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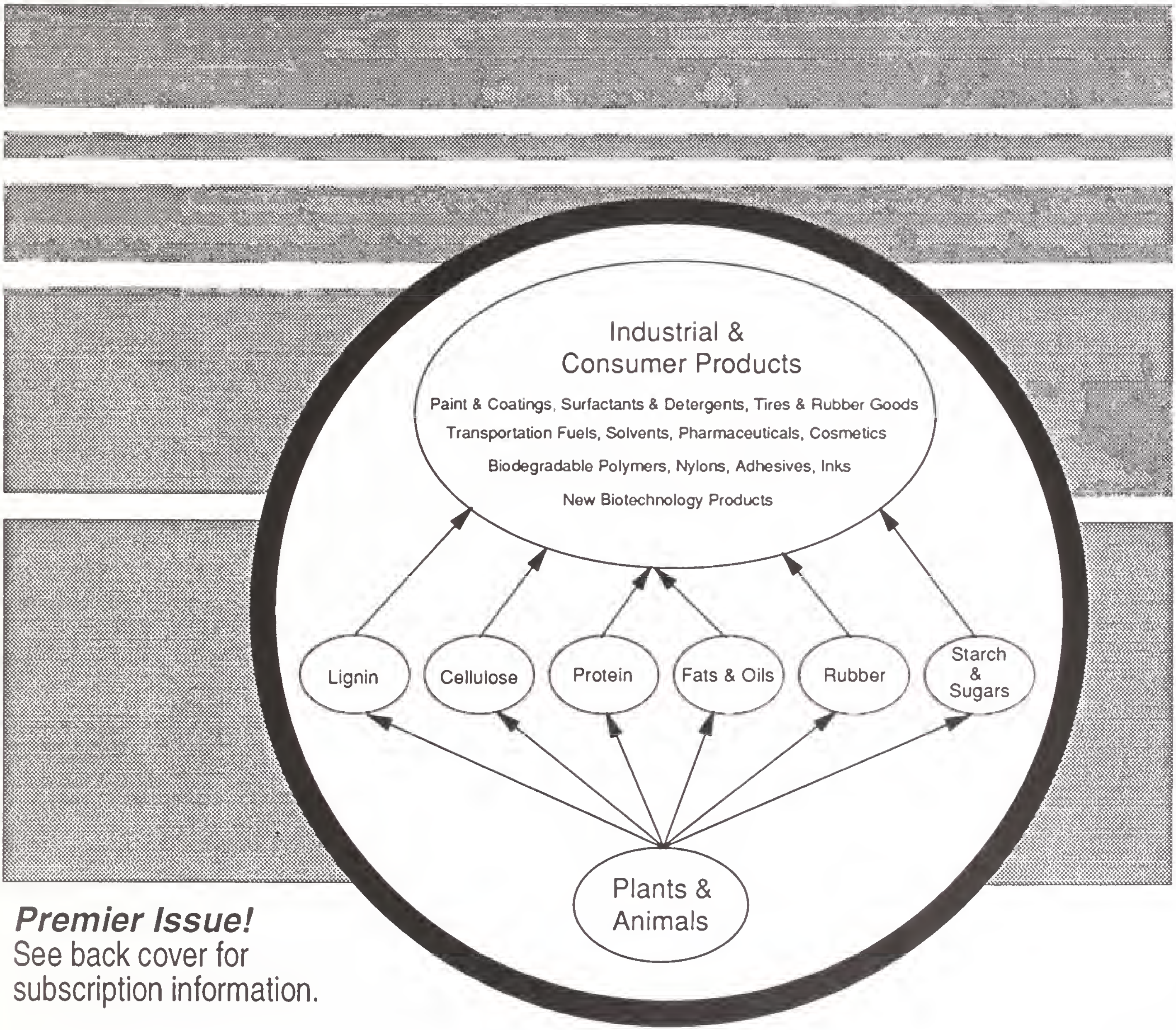
Industrial Uses Of Agricultural Materials

Situation and Outlook Report



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Summary

U.S. Industrial Uses of Agricultural Materials To Continue Rising

Recent scientific advances are reducing the costs of producing and processing renewable resources into industrial products. These include advances that make agricultural production techniques more environmentally benign. And the advances in process engineering--especially in destructive distillation, steam explosion, ultracentrifuges, and membranes--are making agriculturally based products more competitive. The scientific gains, along with Federal and State environmental regulations, and growing consumer preference for "green" products, are increasing the industrial demand for agricultural materials.

Some analysts expect that over the next 3 years the amount of plant matter used in industrial materials, excluding paper and natural rubber, could increase by over 5 million tons, almost double that of 1990.

Given the national economic outlook, housing, textiles, and metal fabricating--key users of agricultural materials--are likely to show above-average growth, while printing and publishing--also key users--probably will show more sluggish growth. Petroleum prices are forecast to rise slightly.

Over the next 4 years, production increases in ethanol, adhesives, and biopolymers will pull up the industrial uses of starches and sugars. Cornstarch is now relatively less expensive than starch from other sources, and has captured most of the market. Translating the demand for starch into corn-equivalents, industrial uses of corn are expected to increase about 140 million bushels to 795 million bushels by 1995/96--up roughly 8 percent per year.

Industrial rapeseed acreage is down, while crambe acreage has risen 150 percent from last year. Derivatives made from these oilseeds are used in slip agents for plastic films, lubricants, and automatic transmission fluids.

Jojoba prices are down, and growers and processors are working to find new uses for the oil. Animal- and plant-based oils are making inroads into surfactant markets. Plus soy ink use continues to grow.

Biodiesel, which can be made from almost any animal or plant fat or oil, is being commercially produced in Europe, and is being tested in the United States as a possible means of meeting Clean Air Act Amendments' emission standards. More testing is needed, but the results so far are favorable.

This year, over 4,300 acres of kenaf, a tropical fiber crop, are being commercially grown in the United States. Kenaf is used for packing materials, bond paper, horticultural mulches, potting mixes, seeding mats, animal litter and bedding, and oil absorbents. Potentially, it could move into newsprint and paperboard markets. Erosion-control products are promising to increase the demand for natural fibers.

According to industry estimates, U.S. beef byproducts are worth $3 billion a year, with most going for industrial uses. In 1992, almost 5.8 billion pounds of inedible tallow was produced, and half was exported. During 1990-92, U.S. production of inedible rendered products rose very slightly. Domestic use slipped over 12 percent while exports rose nearly 13 percent. That partly reflects a switch by U.S. consumers to liquid soap from bar soap.

New products that conserve forest resources are on the rise. Biopulping and other advances in making paper are more efficient and generate less chemical waste. New lumber composites, often made with recycled wood wastes, are reducing the demand for old-growth wood and offer improved performance and design characteristics.

Developing alternative sources of the drug taxol is limiting the long-term opportunities to commercially farm the Pacific yew tree, but there may be some opportunities for growing other species of yews. Some experts predict that in 3 years, taxol will be made from trees on commercially developed plantations, laboratory semisynthesis, cell tissue culture, and fungal metabolites.

Guayule, a desert shrub native to the southwestern United States, is a high-cost source of natural rubber. But a new market may open up for medical gloves, condoms, and other consumer items made from guayule-derived latex for people allergic to hevea-based natural latex products.

Using two probable growth scenarios for starch-based biodegradable polymer output to the year 2000, net farm income will increase slightly and total government deficiency payments will decrease slightly as a result. However, farm output will be largely unaffected. The analysis suggests that increased support for biodegradable polymer research, development, and commercialization would decrease government outlays and increase net farm income.

U.S. ethanol is now mostly made from corn. Future sources may include cellulosic materials, such as short-rotation woody and grass crops. Provisions of the 1990 Clean Air Act Amendments, aimed at controlling carbon monoxide and ozone, are opening up new markets for ethanol along with its main oxygenate competitor, MTBE. Ethanol's near-term demand growth as an oxygenate will depend on regulations expected to be finalized this fall. Over the long term, ethanol has the potential to be a cost-competitive feedstock for oxygenating ethers (ETBE), as well as an alternative fuel.

Introduction

When most people think of agriculture or farming they think of food. Few are aware that what farmers grow can also be used to produce a vast array of nonfood industrial and consumer products.

This lack of knowledge is undertandable. For the past several decades, nonrenewable industrial feedstocks have been considered cheaper than renewable feedstocks and were domestically plentiful. And periodically there have been concerns about whether agricultural resources were adequate to feed the world. During this time, agricultural research and development dollars were primarily spent to improve yields of traditional crops and to develop new food products. The promise of ever-growing international markets kept the focus of the farm sector and public policymakers on traditional products.

Times have changed. Worldwide, the fantastic growth in farm productivity over the last 20 years has caused inflation-adjusted U.S. farm income to decline, a trend that most forecasters see continuing over the next decade. Ever-increasing yields and production efficiencies are outstripping the demand for traditional farm products and reducing job opportunities in rural areas. International commodity markets, once considered easy pickings for U.S. farmers, grow more competitive each day. And it is anyone's guess what will happen to yields of traditional crops--such as corn, soybeans, and wheat--when new advances in biotechnology are brought to bear.

More and more questions are being asked about the true costs of nonrenewable resources. There is mounting evidence of the high environmental costs of recovering, transporting, and using nonrenewable resources. Shrinking U.S. oil production and the Nation's growing dependence on oil imports have added to the debate over the wisdom and cost of an industrial economy that relies so heavily on nonrenewable resources.

This is not to say that agriculturally based industrial products are without environmental costs. Much work remains to be done by government, business, and academia to more accurately measure and account for the full social costs of producing and selling all goods--whether from renewable or nonrenewable resources.

However, changes in the materials and biological sciences are reducing the costs of producing and processing renewable resources into industrial products. These include a number of advances that make agricultural production techniques more environmentally benign. And advances in process engineering--especially in destructive distillation (fast pyrolysis), steam explosion, ultracentrifuges, and membranes--are making agriculturally based products more competitive in the marketplace. The scientific gains, along with environmental regulations at the national and State levels, and growing consumer preference for "green" products are beginning to increase the volume of renewable agricultural resources used by industry.

Many experts believe that the industrial demand for agricultural materials will substantially increase over the next few years. A 1992 report by the Institute for Local Self-Reliance states that, "In the next 3 years, the amount of plant matter used in industrial materials, excluding paper and natural rubber, could increase by over 5 million tons ... almost double ... their 1990 level." The Institute has updated its analysis and the key results are in table 13.

Industrial uses provide U.S. farmers with one of the greatest potential market opportunities in history. Approximately 60 million acres of cropland were idled last year. U.S. farmers have the capacity to produce ample supplies of food and to supply industry with renewable raw materials. Expanding industrial demand for farm products can also help restore economic opportunity in rural communities.

This report is meant to help team up agriculture, industry, government, and academia to produce a new generation of plant- and animal-based industrial products that create jobs and economic activity in rural areas while helping to preserve our environment.

The authors of this report are eager to make it as useful as possible. Suggestions on how it can be made more useful will be enthusiastically received. After you have gone through the report, please fill out the evaluation on the inside front cover, copy it or clip it out, and mail it in.

Mark Dungan
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Industrial Uses: Some Science, Economics, and History

This new Situation and Outlook (S&O) Report covers industrial uses of agricultural materials. New uses and their impacts are highlighted. The report will supply economic intelligence to people involved in all aspects of taking agricultural materials from the farmgate through the industrial marketplace.

Current trends and new projects are covered, but the goal is to provide analysis and forecasts useful to people developing new industrial uses. In this first issue, we focus on defining the subject matter and markets involved, as well as assembling the beginnings of a useful database. We have also made some initial short-term forecasts and longer term assessments.

Each issue will begin with the national and international economic outlook, and how these broad economic forces are expected to affect key industrial sectors that buy or potentially buy agricultural materials. Next come Sections for six categories of agricultural materials: Starches and Sugars, Fats and Oils, Fibers, Animal Products, Forest Products, and Specialty Plant Products. Each of these Sections covers traditional uses, new uses currently in the marketplace, and uses on the horizon. Each has a flow chart that depicts how the materials move from the farm through various processing stages and intermediate products to end uses.

Special (i.e., feature) articles in this issue focus on the prospects, and likely effects, of increasing production of starch-based polymers, and the role of ethanol in the U.S. automobile fuel market. Future special articles will look at the implications of growing more industrial oilseeds; the prospects for, and likely economic effects of, biofuels; the role of government in developing industrial uses; methods for evaluating proposed projects for public funding; and case studies of developing and commercializing new uses.

Data published here come from many government agencies, private publications, trade associations, producer and processor groups, and industry sources. We asked for information from a wide range of individuals and organizations. Many thanks to those who took the time to send us their material. Please send us information you think we can use and we will try to include it in upcoming issues.

Chemical Building Blocks Are the Foundation

To explain how materials move from farms and forests to become industrial and nonfood consumer products, some chemistry background is necessary. Plant and animal materials are made up of different combinations of carbon, oxygen, hydrogen, and nitrogen. The categories used here are different groups of organic compounds suited to different applications. Plant and animal matter can be further grouped into several key components: carbohydrates, oils (almost all are triglycerides), proteins, and lignin (a component of woody plants).

Carbohydrates are made up of carbon, hydrogen, and oxygen and are the most plentiful organic compounds. Over three-fourths of the dry weight of all vegetation is carbohydrates. Carbohydrates are divided into sugars, starch, cellulose, and natural gums. Starch is similar to cellulose but can be more easily broken down into sugars through hydrolysis, and then into alcohol by the action of microbes in a process called fermentation. Cellulose is harder to break down with traditional fermentation processes because it will not dissolve in water and is partially crystalline. In addition, cellulose is often bound together with lignin, a resinous chemical that provides rigidity to wood, which also makes it difficult to ferment. Woody crops are often called lignocellulosics because lignin is a significant component, which has industrial applications.

Fats and oils come from a wide range of plants and animals. The only distinction between fats and oils is that fats are solid at room temperature, while oils are liquids. They can be grouped according to their various chemical properties: drying (linseed, tung), nondrying (castor, coconut, lard), edible (corn, soybean, canola, olive), and inedible (industrial rapeseed, castor, crambe, and inedible tallow). Essential oils are volatile liquids from plants used in perfumes and flavorings, and are not triglycerides.

Proteins are chains of amino acids connected by peptide linkages. They are in the cells of all living things, but are generally more concentrated in animal products. They come as enzymes, hemoglobin, hormones, viruses, genes, and nucleic acids, and are the basic components of connective tissues. Leather, silk, and wool are the protein materials most familiar to the public.

Enzymes are biological catalysts for numerous chemical reactions, and are of growing importance in industrial applications. Catalysts increase the rate of a chemical reaction without themselves being consumed by the reaction. Using enzymes as catalysts can cause complex chemical reactions at low temperatures and pressures. That is an advantage over most inorganic catalysts that require high temperatures and pressures to cause simple reactions.

Manufacturing industrial and nonfood consumer products from agricultural materials requires initial processing of the materials into their more basic components. This involves milling, rendering, crushing, chopping, refining, and so on. The results include the building blocks of our categories: starches and sugars, fibers, fats and oils, various protein meals, and other higher value compounds. These are then put through different chemical, biochemical, or thermochemical processes. Outputs are second-generation products including polymers, fatty alcohols, gelatin, fiber pulps, and other intermediate chemicals. These go through additional conversion and manufacturing stages to become the products used by industry and consumers.

Fossil fuels (petroleum, coal, natural gas, and lignite) go through similar stages from raw material to end product. Initial processing of petroleum involves desalting and dewatering. Petroleum then flows into distillation and different "cracking" processes where heat and metal catalysts are applied to separate different grades of fuels, oils, and residual tars. Many of these second-generation products then go through further processing to be turned into plastics and specialty chemicals before they are sold to industry and consumers. Coal has to go through even more extensive processing stages to be converted into coke, coal tars, and other products.

Natural gas is processed by first removing nonhydrocarbon gasses, and then it is distilled into processed natural gas--methane, ethane, propane and others--for fuel and chemical use. Natural gas also supplies ammonia, methanol, and other compounds. Ethylene, a widely used petrochemical feedstock, is made by cracking ethane and propane. Ethylene, benzene, and other refined petrochemicals must go through further processing to become industrial and consumer products.

Hydrocarbons are exclusively compounds of hydrogen and carbon. They are primarily from petroleum, coal tar, and

some plants. Plants containing hydrocarbons include hevea rubber and guayule, which are covered in the Specialty Plant Products Section. The distinction between hydrocarbons and carbohydrates is that carbohydrates contain oxygen. Because of the oxygen, plant-matter feedstocks are typically more bulky and require less energy to break down into refined products. In addition, they generally result in fewer chemical byproducts that are harmful to the environment. However, carbohydrates are mechanically more difficult to process on a large scale than hydrocarbon liquids and gasses.

Why Industrial Products From Agricultural Materials?

Industrial uses of farm products are making a comeback because public concern about pollution and the environment has intensified and new, less costly technologies for processing agricultural materials have become available. In addition, farmers need more market opportunities beyond traditional food, feed, and fiber products. Partly because of the environmental and social implications, a unique coalition of people from industry, government, the research community, environmental interest groups, and farmers' associations are working together to increase the use of farm and forest materials by industry.

Early in the industrial revolution, virtually all industrial inputs were based on plant and animal products. Vegetable oils were used to make paints, varnishes, linoleum, and soaps. In the 1840's, mechanical processes for pulping wood were developed, and with new chemical processes beginning in the 1850's, the modern paper industry was born. Wood was also used to make charcoal for smelting iron. Methanol, a byproduct, was used as an industrial solvent and later to produce the first generation of plastics. And grain alcohol (ethanol) was a key industrial solvent and fuel prior to an 1862 tax on both beverage- and industrial-grade alcohol.

Around the turn of the century--when environmental pollution was not a major public concern--new technologies began making less expensive and high-quality products available from nonrenewable fossil fuels. By the mid-1920's and 1930's, coal and petroleum and their derivatives were squeezing out many agricultural materials, and much of the Nation's research funding focused on developing products from fossil fuels. The Institute for Local Self-Reliance estimates that plant-based materials still accounted for about 35 percent of industrial inputs in 1925, but by 1989 that share had dropped to less than 16 percent, mostly for producing paper.

Plastics are a case in point. In the last half of the 19th century, several plastics derived from plant products were developed, such as celluloid. Commercial successes came in the early 1900's when moldable plastics from plants became useful to manufacturers of cars and other consumer goods. But petroleum-based plastics, led by the invention of vinyl chloride in 1913, outperformed plant-based polymers in quality and price. By the end of World War II, petroleum ruled the plastics market.

What Is Government's Role?

Why is government helping to develop new uses from plant and animal products? Because market incentives for private research and development of new industrial uses are often limited, resulting in underinvestment. The private sector underinvests because:

- Firms cannot capture all the profits from their research,
- The environmental costs of competing products are not reflected in their prices,
- Farm price- and income-support programs dilute producers' incentive for demand-creating research, and
- Firms may value near-term payoffs more highly than does society.

Looking at each of these in turn:

Research appropriability becomes an issue when research and development lead to knowledge with wide-ranging applications, and result in products that benefit society more than individual businesses. Goods with such properties cannot be as profitably merchandised, even though the gains to society may be significant. Firms cannot capture all the profits from goods with collective properties. Private goods, on the other hand, allow the owners of the associated property rights or patents to collect all the profits.

Some analysts argue that small producers serving a single market are less likely to undertake wide-ranging research and development projects than large firms that are vertically integrated--owning companies that control production from the extraction of the raw material to the end product. So, for example, appropriability could be more of an issue for agriculturally based materials than for petrochemically based materials.

Environmental externalities of products involve environmental costs and benefits that affect society but do not enter the profit calculations of firms. Without collective action, markets simply do not take into account environmental costs when allocating resources among productive uses. For petroleum-based plastics and other products having negative externalities, the price consumers pay does not include environmental impacts, waste disposal costs, and other costs associated with these products.

One approach to government intervention would be to impose a tax on plastics to cover disposal, recycling, and environmental costs. Without such a tax, environmental externalities act as a barrier to entry of more "environmentally friendly" alternatives, like starch-based polymers. Starch-based polymers can be fully degradable, but their cost is currently greater than the cost of petroleum-based plastics.

Another intervention route is for government to support research and development activities to reduce the private costs of starch-based polymer production. See the Starches and Sugars Section and the first special article for specifics.

A broader approach would involve the creation and implementation of full-cost accounting. Economists at numerous organizations--including the United Nations, the World Resources Institute, and ERS--are developing national income and product accounts that incorporate the value of the natural and environmental resources consumed. Some in industry and government are developing a system called "Life Cycle Analysis" that tracks a product's full costs, from raw materials through disposal. However, moving to such a system will require strong public intervention, because any single company that prices products to include the social environmental costs cannot long survive in a competitive market. And a competitive market is the least-cost system for allocating scarce resources that are privately owned.

The structure of Federal farm price- and income-support programs means that deficiency payments decline when market prices rise. So, the government has an incentive to fund projects developing new uses because demand-creating innovations can cut the costs of farm-income-support programs. A technological breakthrough, for example, in the production of starch-based polymers would increase market demand for corn or wheat and reduce program payments. See the Starches and Sugars Section and the first special article for more on this.

Similarly, innovations in the development and use of new crops that are economically viable alternatives to program crops could also reduce the costs of farm-income-support programs. For example, if the demand for kenaf increased sharply, its price would rise relative to the prices of program crops. Some farmers would then shift acres away from program crops to grow kenaf. With less acreage in the programs, Federal payments would decline.

Short planning horizons lead some private firms to underinvest in research and development because they value near-term profits more highly than does society. Also, risk-averse firms may reduce research and development below what is socially optimal. Studies differ on whether these risk- and time-preference differences exist and whether they justify government intervention.

"Short-termism" in business planning has many dimensions. U.S. industrial structure and corporate ownership patterns tend to support investments with higher short-term payoffs compared with the economies of Japan and Germany. The funding rate of precommercial research and development in Japan and the European Community (EC) is higher than in the United States. Through efforts like the MITI and Key Technologies programs, Japan has promoted partnerships downstream from basic research--between business, universities, and government. Similarly, the EC has promoted collaborative research and development under the Framework Program.

Government-induced structural barriers, as well as standard business practices, may be factors limiting investment in precommercial research and development in the United States. For example, U.S. laws keep ownership of banks and nonfinancial corporations separate, creating pressure for higher short-run payoffs to repay loans. This is not the case in many other countries.

However, public efforts to boost technology transfer in Europe and Japan have had mixed results. There is broad agreement among economists that the United States must develop programs in which government does not try to pick technological winners, but rather promotes financial support of research, development, and demonstration activities that are economically efficient--stepping in only where there is a market failure.

New Institutions Promote Adoption

Since the 1940's, agricultural research and development have helped boost productivity by 230 percent. However, the government's share of research funding, has trended downward, from about 50 percent in the 1960's and 1970's to less than 45 percent in the 1980's, and likely will continue to drop. Many analysts believe that to get the biggest bang for each research dollar, more Federal support is needed at the applied, development, and demonstration (precommercial) stages to move basic research advances into the marketplace.

Congress set up the Alternative Agricultural Research and Commercialization (AARC) Center under the 1990 Farm Bill, which supports precommercial development of nonfood, nonfeed uses of agricultural materials. Through the AARC Center, Congress is trying to bridge a funding gap and an institutional gap. The institutional gap arises because the link is weak between scientists making discoveries and the firms marketing new products. The funding gap arises in part because risk remains high and costs tend to increase sharply at the precommercial stage. So capital is often lacking to develop technologies emerging from the laboratory but not yet ready for commercial prototyping.

According to estimates from the Department of Commerce, for each dollar spent on research, $10 is spent on development and $100 on precommercial activities before a new product reaches the market. The point between development and commercial production is where technology transfer often fails. The AARC Center is especially situated to help private industry bridge the funding gap and bring new-use commercial technologies to the marketplace. The Center and private firms share funding risks and the returns from the marketplace. The Center funds projects on a competitive basis and only when there is a strong financial commitment from a private partner. Specific projects the AARC Center is funding this year are in the final stages of negotiations and will be covered in the next issue.

The AARC Center is also establishing two regional centers this year to enhance grass roots participation in developing new uses for agricultural materials. The host institutions, chosen through a competitive process, will be the Kansas Industrial Agricultural Consortium and the Northern Regional Agricultural Utilization Consortium, which currently includes Minnesota, North Dakota, and South Dakota.

Through public-private partnerships, USDA's Cooperative State Research Service, Office of Agricultural Materials is

also helping to bridge the gap through joint ventures with industry, universities, and other government agencies. They are supporting the development of products ranging from vegetable-oil-based lubricants and polymers to kenaf newsprint and bond paper, to guayule rubber tires.

The Technology Transfer Act of 1986 promotes technology transfer by authorizing Cooperative Research and Development Agreements (CRADA's) between government scientists and private companies to develop particular discoveries. These agreements give private companies exclusive rights to develop government discoveries for a given time period, but no transfer of public funds is involved.

Since 1986, scientists at USDA's Agricultural Research Service (ARS) have established over 300 such agreements with companies to commercialize technology arising from their research, while USDA's Forest Service has established 50 agreements. USDA and the Department of Energy (DOE) are the lead Federal departments in setting up CRADA's.

DOE's Office of Industrial Technologies runs an Alternative Feedstocks Program. The goal is to develop precompetitive and environmentally acceptable technologies for producing high-volume chemicals and materials from renewable resources, namely agricultural and forestry materials.

The program has recently examined opportunities for about 70 chemical and material products from renewables. The evaluation was done by a National Laboratory Team with input from industry. The Team includes the National Renewable Energy Laboratory (Golden, CO), Argonne National Laboratory (Argonne, IL), Idaho National Engineering Laboratory (Idaho Falls, ID), Oak Ridge National Laboratory (Oak Ridge, TN), and the Pacific Northwest Laboratory (Richland, WA).

Based on this study, the program is evaluating opportunities to use biomass to produce succinic acid and butanol. More generally, the program is looking at the use of clean fractionation to convert lignocellulosic biomass into cellulose, hemicellulose, and lignin as future chemical building blocks. The program will form partnerships with industry to develop and commercialize these uses of agricultural and forestry materials.

Among the nonprofit groups working to develop industrial uses of agricultural materials is the New Uses Council. Incorporated in Kansas, its mission is to seek commercial development of new nonfood, nonfeed products made from renewable farm-based commodities through education, advocacy, information dissemination, and public-and-private-sector partnerships.

The Institute for Local Self-Reliance (Washington, DC) is another nonprofit private group interested in developing industrial uses of plant and animal products. The Institute works to achieve a dramatic reduction in U.S. per capita consumption of raw materials, and to help the economy shift from fossil fuels to renewable resources. While some of the estimates from the Institute tend to be more optimistic than the estimates elsewhere in this report, see table 13 for a comprehensive assessment of the potential for industrial uses of plant matter. Their estimates are based on several years of research and close contact with industry and academia.

While these organizations are playing leading roles in advancing industrial uses of agricultural materials, support does not end with them. Many other State and local groups and commodity associations are also advancing these concepts. [Gregory Gajewski, Douglas Beach (202) 219-0085, and Irshad Ahmed (202) 232-4108]

Current Macro and Industrial Outlook

Moderate increases in demand and modest increases in costs expected for the rest of 1993 and 1994 will provide a supportive environment for agricultural producers selling to the industrial sector. Inflation and interest rates are expected to remain low. Business spending on plant and equipment is likely to lead the expansion. Petroleum prices are forecast to rise slightly. Housing, textiles, and metal fabricating--key users of agricultural materials--are likely to show above-average growth, while printing and publishing--also key users--probably will show more sluggish growth.

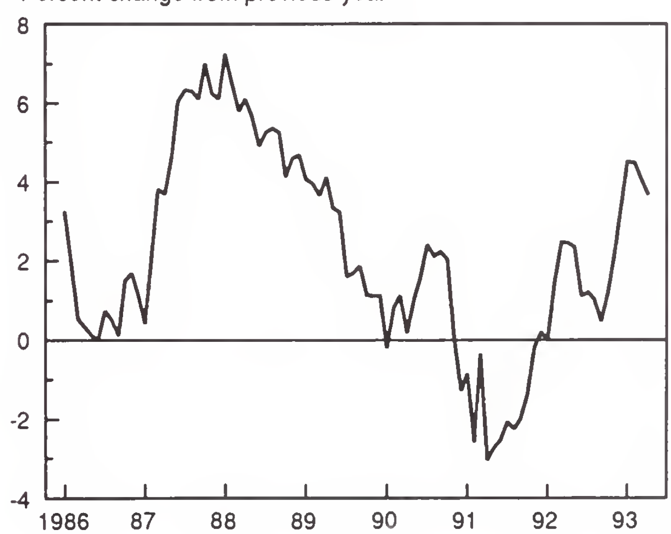
Modest U.S. Economic Growth Ahead

Most analysts expect that inflation-adjusted Gross Domestic Product (GDP) will grow at a 3-percent annual rate through the end of 1994. This is consistent with 3.5- to 4-percent annual growth in industrial production (figure 1). Although this faster growth should push down unemployment, the unemployment rate is likely to remain relatively high. Unemployment rates in rural areas, which fell below the overall rate in 1992, are likely to remain close to rates in urban areas.

Figure 1

Industrial Production

Percent change from previous year



Coupled with this relatively high unemployment rate, low industrial-capacity use should help keep inflation around where it is now: about 2 percent for overall producer prices. Interest rates are expected to rise slightly as the economy gathers strength, but still remain very low by historical standards.

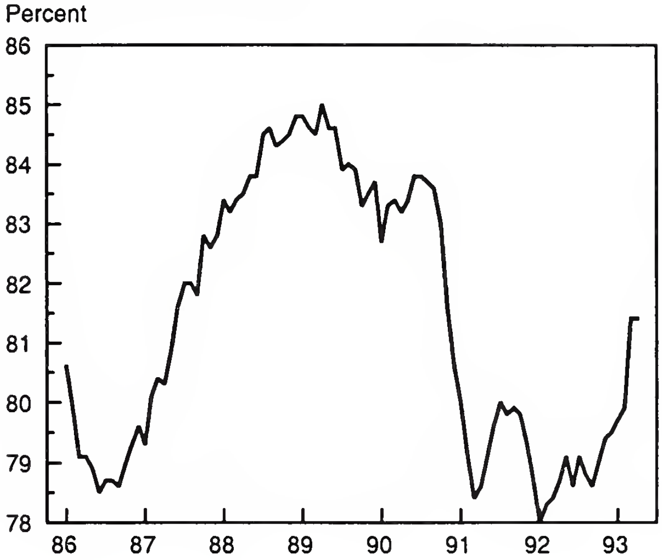
Business spending on plant and equipment and residential building are the two areas most likely to lead overall GDP growth. A Census Bureau survey suggests that businesses plan to increase inflation-adjusted (i.e., real) spending on new plant and equipment by 6.4 percent in 1993. Further, housing starts are generally expected to be up 10 percent in 1993 and then rise another 4 percent in 1994.

Growth in consumer spending is likely to be slightly slower than the growth in GDP, as consumers attempt to rebuild their low savings and reduce debt levels. This suggests less growth in industries that supply primarily to consumers in 1993 and 1994. Government purchases at all levels are expected to decline slightly over the next 18 months, signaling continued contraction in industrial demand from those sources.

Cost pressures should be minimal over the next 12 to 18 months. Low interest rates should keep interest expenses down, and provide an opportunity to expand production or processing lines. Wages have been declining recently, and with a relatively high unemployment rate, are not likely to accelerate soon. Unit labor costs in manufacturing fell 0.5 percent in 1992, the largest decline since 1987.

Although the latest recession brought about average declines in industrial production and capacity use, the subsequent recovery has been much slower than average. Twenty-five months after the trough of the 1991-92 recession, overall production has risen by only about 8 percent, less than half of the increases achieved at the same point in previous recoveries. Factory output has shown a similar sluggishness, although it has risen slightly faster than total output. Between the recession's end and April 1993, manufacturing production grew just over 9 percent. Capacity utilization has also inched up slowly (figure 2). The utilization rate rose only 4 percent since the March 1991 trough, compared with increases of nearly 8 percent and more than 10 percent during the last two recoveries.

Figure 2
Capacity Utilization Rate



Defense Cuts Slow Industrial Growth

Many analysts suggest that reduced defense spending has contributed substantially to slow growth in overall industrial production since the recession's end. From the first quarter of 1991 through the first quarter of 1993, Federal purchases of defense goods and services fell more than 4 percent (figure 3).

The defense-spending decline has affected manufacturing by directly reducing production in some industries, such as aerospace manufacturing and shipyard work. The decline has had large indirect effects on many other manufacturing industries that supply defense-related manufacturers with inputs, such as metalworking machinery.

The defense-spending decline projected over the next few years points to continued restructuring for some industries, perhaps leading to continued sub-par industrial production growth. However, if defense-spending cuts are used to reduce the Federal deficit, the Federal demand for credit will fall and interest rates would likely decline, increasing demand for most industries.

Falling Interest Rates Help Lift Investment

Because financial markets have already incorporated some degree of lower Federal spending into their expectations, some of the interest-rate decline has already occurred. For example, yields on long-term bonds fell about 50 basis points (100 basis points equal a percentage point) in the early part of 1993, which most analysts attribute to the expectation of reduced Federal credit demand.

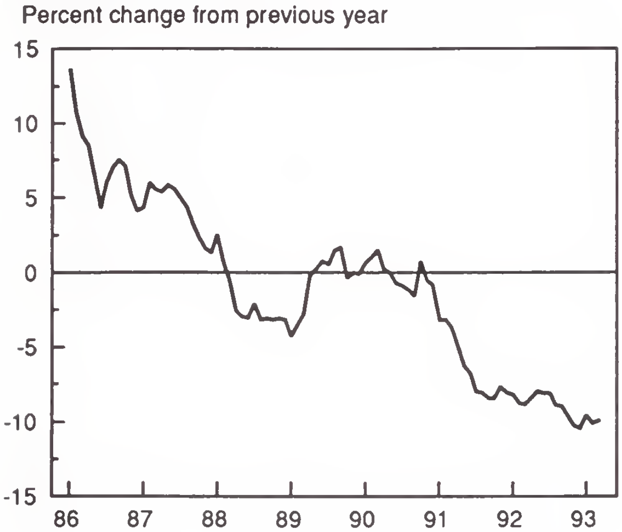
Short-term rates declined less than long-term rates. Yields on 3-month Treasury bills fell below 3 percent in February and have remained there since. Overall, short-term rates are the lowest in about 30 years. At about 6.7 percent in April 1993, yields on long-term Treasury bonds are the lowest they have been in about 17 years. Low long-term interest rates keep down the costs of financing new plant and equipment and more generally lead to expanding consumer and business spending.

Foreign Developments Point to Modest Export Growth

U.S. export growth slowed in 1992 and is not likely to accelerate in 1993. Although the foreign-exchange value of the dollar remains low and fell slightly through the first 5 months of 1993--keeping U.S. exports competitive in foreign markets--economic growth abroad has slowed substantially.

Figure 3

Production of Defense and Space Equipment



Agricultural exports in 1992/93 are forecast at $42.5 billion, virtually unchanged from a year earlier.

Growth in Germany and other parts of Europe was held down by high German interest rates, where tight monetary policy was imposed to ward off the inflation prompted by reunification. Growth in Japan slid as the economy retreated from its unsustainably rapid growth of the late 1980's. Neither country is expected to recover substantially in 1993; German GDP is expected to decline close to 2 percent and Japan's economy is expected to grow only 1 percent.

Both countries are expected to recover somewhat in 1994. Faster growth in those countries is likely to help support growth in the U.S. industrial sector in 1994. Although the value of the dollar is expected to rise as foreign interest rates decline relative to U.S. rates, the increase is not expected to be a serious drag on U.S. export performance in either 1993 or 1994.

Textiles, Metal Fabricating Show Strongest Potentials

Although some industrial uses of agricultural products depend more on the general economy--for example, using various plant extracts and oils as lubricants or using ethanol or biodiesel as a fuel--others are tied more closely to specific industries--such as fibers, inks, and paper.

Textile production fell at about a 2-percent annual rate for the 6 months ending April 1993, compared to 9.2-percent growth during 1991 and 4.5-percent growth during 1992. Recently, some specific textile industries have been sluggish. Since October, fabric production has remained flat and production of overall knit goods has fallen about 1.4 percent.

Production of carpeting dropped 14.2 percent. However, output of yarns and miscellaneous textiles rose by 1.4 percent. Textile output is one barometer of the likely demand for kenaf, jute, hemp, sisal, and milkweed fibers. For example, kenaf fibers are now being used in degradable mats for seeding grass. If overall housing activity and consumer spending is spurred by the relatively low interest rates, then some of these industries may experience better than average production increases over the next year or so.

Printing and publishing production has risen more slowly than overall industrial production recently, rising only 1.5 percent during the last 6 months. Industry output fell 4.5 percent during 1991, and another 0.8 percent during 1992. By the end of 1992, output was down 1.8 percent from the end of 1989. The growth of the printing and publishing industry--which includes newspapers, books, periodicals, and other printing--gives some indication of the health of the market for soy and other vegetable inks and many fibers that rely on paper demand. A more robust outlook for this sector would help the commercialization of kenaf as a material for newsprint and other types of paper.

Production of fabricated-metal products has climbed 6.2 percent in the last 6 months, well above the pace of overall production. Production fell 1.1 percent during 1991, but rose close to 3 percent during 1992. However, by the end of 1992, it was still 1.1-percent below the level at the end of 1989. This industry is important to industrial rapeseed and crambe oils, which are used as raw materials for lubricants in the rolling and stamping of metal products.

Construction governs the demand for many forestry products, particularly lumber. The housing market was hit significantly during the recession. Housing starts fell 13 percent in 1990 and 15 percent in 1991. But in 1992, starts rose 18 percent, and in April 1993 were about 11 percent above a year earlier. Other indicators suggest a continued rebound in construction activity: building permits, an indicator of future construction activity, rose 6 percent for the 12 months ending in April. Continued relatively low long-term interest rates should prove beneficial for further growth in the housing market, which will boost the demand for lumber and related forestry products.

Petroleum Prices To Increase Slightly

Developments in energy markets have major implications for overall industrial markets as well as for industrial uses of agricultural materials. A sharp increase in the price of oil, for example, would tend to reduce overall economic activity and raise costs, but would also stimulate production of alternatives to petroleum-based fuels and lubricants, including those derived from agricultural materials.

The major factor which determines the price of petroleum-based products is the price of crude oil, with weather and domestic and foreign macroeconomic growth as important secondary factors. Politics, OPEC, and foreign affairs also play a key role as the United States imports about 45 percent

of its petroleum. A good proxy for a single market price of crude oil is the weighted-by-sales cost of crude oil imported into the United States--known as the refiner acquisition cost (RAC).

The commonly reported price of West Texas Intermediate crude oil will be between $2 or $3 per barrel (42 U.S. gallons) more than the RAC. The Energy Information Administration's (EIA) short-term forecast has the RAC averaging $18.34 in 1993 and $19.51 in 1994. The RAC was $18.22 in 1992 and, in the first quarter 1993, it was down to $17.27. EIA projections are consistent with moderate economic growth both for the United States and other industrialized countries. Some analysts see an even slower crude price growth in the near-term, pointing to possibly more sluggish growth in industrialized countries in 1993 and 1994.

The EIA estimates a current global excess capacity in crude oil production of 1 million barrels per day. Over time, world economic growth will tend to raise fuel demand, while the former Soviet Union's oil production is likely to decline further. As excess capacity is eliminated, the RAC is likely to rise in real terms. Only an expectation of severe future market tightness, as during the Gulf war, or abnormally bad weather could induce the RAC to rise sharply before the above balance is restored.

EIA forecasts that the real price of oil will rise in the second half of 1994 as lower crude oil capacity balances increased demand. Other analysts suggest that real oil prices will not rise substantially until well into 1995, due to weak world growth. In their opinion, the RAC would stay below $19 until 1995. Gasoline prices are expected to peak at about $1.29 per gallon in late 1994. Diesel prices should peak at $1.26 per gallon about the same time. [Ralph Monaco, Jennifer Beattie, and David Torgerson (202) 219-0782]

Starches and Sugars

Over the next 4 years, increases in the production of ethanol, adhesives, and biopolymers will pull up the industrial uses of starch and sugar (figure 4). The degree of market penetration in these markets is closely tied to environmental developments. In most of these markets, biobased products have a clear advantage environmentally, compared to synthetic substitutes.

The analysis here assumes that corn is the feedstock. Other sources of starch and sugars include barley, potatoes, sorghum, wheat, and woody crops. Cornstarch is now relatively less expensive than the starch from these other sources, and has captured most of the market. With that and other assumptions, industrial uses of corn are expected to increase by about 140 million bushels to 795 million bushels by 1995/96. This translates into an annual increase of roughly 8 percent per year (table 1). Over the long term, increases in the demand for ethanol will improve opportunities for short-rotation woody and grass crops.

Table 1--Industrial use of corn, 1990/91-1995/96

Marketing year 1/	Starch	Fuel alcohol	Total industrial demand
		--Million bushels--	
1990/91	197	349	546
1991/92	201	398	599
1992/93	204	410	614
1993/94	208	445	654
1994/95	217	503	720
1995/96	226	568	795

1/ Marketing year beginning September 1. 1992/93-1995/96 are forecast.

Fuel Ethanol Use To Accelerate

Industry estimates place the combined demand for fuel-oxygenate additives--as a result of the 1990 Clean Air Act Amendments (CAAA)--at 3.7 billion gallons of ethanol equivalent by 1995/96, or more than 3 times current ethanol production. Market analysts project that corn-based ethanol will capture approximately 35 percent of the oxygenated fuels market by 1993. This implies a demand for ethanol of 1.3 billion gallons by 1995/96. As a result, an additional 123 million bushels of corn could be needed during 1992/93-1995/96 for the fuel-ethanol market. This would raise total use of corn for fuel-ethanol production to approximately 568 million bushels by 1995/96. See the second special article for more on ethanol.

Since the late 1970's, ethanol has been used as a gasoline extender by blending one part of ethanol with nine parts of gasoline to produce "gasohol." This 1/10 ratio is the technical definition of gasohol. Ethanol production has grown from 20 million gallons in 1979 to almost 1 billion in 1991. From September 1992 through February 1993, corn used to make fuel rose 6 percent.

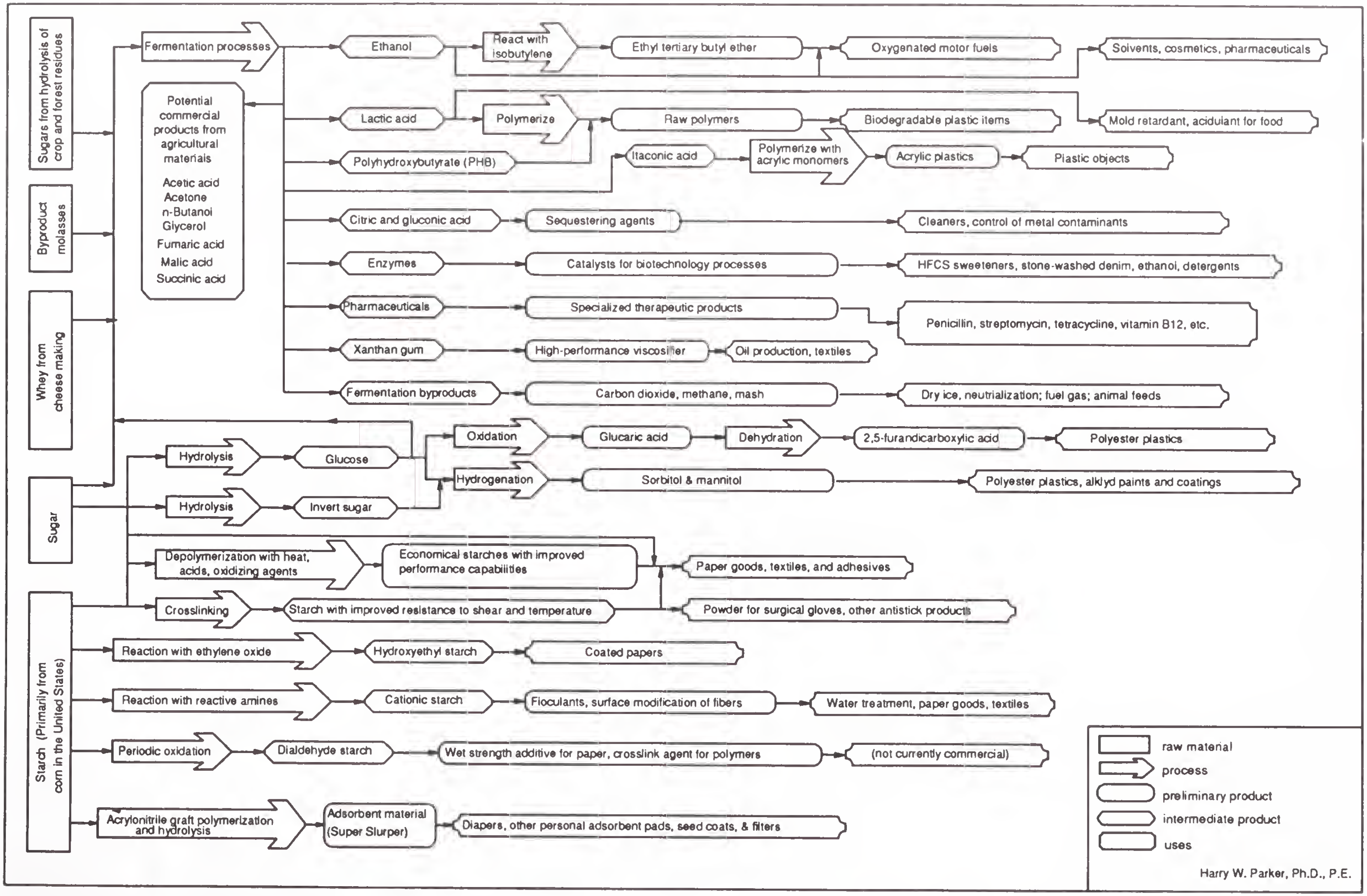
To achieve this expansion, corn-based ethanol has been and is highly subsidized. These subsidies have elements of both research and development funding (e.g., Federal loan subsidies by USDA and DOE for physical plant) and direct production support.

Private and public research and development have helped transform corn-based ethanol production from a negative energy balance to a positive energy balance. The energy value of one gallon of ethanol is 76,000 Btu (British thermal units). As late as the mid-1980's, the total energy necessary to produce one gallon of ethanol was 120,000 Btu and the energy credit for the coproducts (corn oil, gluten feed, gluten meal, and carbon dioxide) was 32,000 Btu [3]. This gave a net energy loss of 12,000 Btu.

Currently, the total energy requirement for an average-efficiency corn farm and an average-efficiency ethanol plant is 75,811 Btu. The coproduct energy credit is 24,950 Btu--resulting in a net energy gain of 25,139 Btu. So, corn-ethanol production has gone from a net energy sink, requiring

Figure 4

Processing Starches and Sugars into Industrial and Consumer Products



16 percent more energy than it produced, to a net energy producer, yielding a 33-percent energy surplus [2].

Increases in ethanol production can decrease farm program costs by raising grain prices. Moreover, an increase in the price of corn generally lifts all other feed-grain prices, thus lowering the cost for all feed-grain programs. A recent USDA study projected that annual U.S. corn-based ethanol consumption would increase gradually from 800 million gallons in 1987 to 2.7 billion gallons in 1995. Lost government revenues due to the 5.4 cent-per-gallon subsidy of ethanol-blended fuels would cost the Federal government an estimated $5 billion. This was offset by a $9-billion decrease in Federal-farm-program payments, resulting in net Federal savings of $4 billion [1].

A second, possibly more significant advantage of the corn-ethanol program may come from the CAAA. The Environmental Protection Agency (EPA) estimates that nationally, cars and trucks contribute 56 percent of carbon monoxide emissions, 43 percent of volatile organic compounds (VOC) emissions, and 57 percent of nitrogen oxide (NOx) emissions. Carbon monoxide can be lethal in high concentrations. VOC's and NOx contribute to ground-level ozone formation, which can lead to various respiratory problems.

In response to these health hazards, Congress enacted the CAAA in 1990. This legislation amended existing Federal clean air laws by defining standards for nonattainment areas where air quality goals are not met. The CAAA also mandated the sale of reformulated or oxygenated gasolines in nonattainment areas.

The first stage of the CAAA was implemented last November. The Act required a 2.7-percent oxygen content by weight for fuels sold in 39 metropolitan areas not meeting carbon monoxide goals for at least 4 winter months. The addition of 10-percent alcohol to gasoline gives an oxygen percentage of 3.5 by weight, well above the amount necessary to meet the requirements.

Use of alcohol might have been even higher in 1992/93 if California had kept its 2.7-percent oxygen requirement rather than reducing it to 2.2 percent, and if New York had not delayed the start of its program. Supplies of a petroleum-based oxygenate, methyl tertiary butyl ether (MTBE), were built up for the program. Petroleum producers added manufacturing capabilities for MTBE. Spot prices of all oxygenates declined during the November 1992-February 1993 program period because of plentiful supplies.

The second stage of the CAAA is to be implemented in 1995. It requires reformulated gasoline in the nine worst ground-level ozone areas. According to the legislation, reformulated gasolines must reduce VOC's and toxic emissions by at least 15 percent, and generate NOx emissions no higher than those of 1990 baseline gasolines. Because splash-blended gasohol may increase evaporative VOC emissions and MTBE does not, ethanol-gasoline mixtures will require lower evaporative emissions from the gasoline component than MTBE-gasoline mixtures. Depending on the cost of decreasing gasoline's evaporative emissions, this could drive up the relative price of gasohol as compared to MTBE-gasoline blends. However, the rules are not yet final and there are several proposals that provide incentives for renewable oxygenates. See the second special article for more on ethanol.

Starch To Continue Dominating Adhesives Market

In 1990, U.S. adhesive consumption was about 5 million short tons with an estimated market value of over $2 billion annually. Natural adhesives accounted for over 40 percent of the market then, and have continued to hold on to that share. Domestic demand for adhesives is projected to exceed 5.5 million tons by 1995/96—an increase of 2.4 percent annually. This translates to an additional 600 million pounds of cornstarch, or an 18-million-bushel increase in corn demand by 1995/96.

Starch dominates the natural adhesives market. Currently, nearly 3.5 billion pounds of corn-starch equivalent is used annually to make adhesives, primarily for the paper and paperboard industry. While the majority comes from corn, starch from wheat and potatoes is also used to make adhesives.

The binding substances in adhesives and glues come from resins, rubber, inorganic and organic compounds, vegetable oils and milk proteins, gelatin (derived from both animal fat and synthetic routes), and even eggs. Synthetic adhesives are tougher and generally more water resistant than the natural adhesives. However, environmental concerns over synthetic adhesives have spurred new technologies using plant-derived starch. Many of these new systems are intended for the packaging market. The success of marketing natural starch-based adhesives in the packaging industry is directly associated with the solid waste disposal problems faced by petroleum-based plastic films. Adhesives, both natural and synthetic, generally cost from 15 cents per pound to $50 per pound or more for specialty products.

Starch adhesives are usually less expensive than synthetic adhesives and are free from the unpleasant odors of some animal glues. Uses include paper carton and bottle labeling, stationery, and some interior plywood fabrications. Perhaps the most well-known use of starch glue is to attach postage stamps.

Biodegradable Polymers To Gain Market Share Slowly

In 1992, biodegradable-polymer resins captured less than 5 million pounds or roughly .08 percent of the plastics resin market. Provided that Congress does not mandate increased biodegradable-polymer use, market penetration into the 8-billion-pound nonfood packaging market will likely be quite slow. The most conservative estimate of biopolymer consumption puts total demand at roughly 8.4 million pounds of resin in 1995/96.

Starting from a base of 5 million pounds in 1992/93 and assuming an average starch-loading technology of 50 percent, biopolymer demand for corn would equal approximately 124,000 bushels in 1995/96. See the first special article for details.

Four markets have been targeted for biodegradable-polymer applications: food packaging, nonfood packaging, personal and health care, and other disposables. Degradable food packaging is not addressed here because the Food and Drug Administration (FDA) has not yet established guidelines for its use. So, nonfood packaging is the key market for the near future.

The MARPOL Treaty, signed in 1987 by 29 countries including the United States, prohibits the discharge of all plastic wastes at sea beginning in 1988 for commercial vessels and in 1994 for government ships. EPA estimates that 4,205 metric tons of plastic wastes are produced each year aboard government ships. Adding merchant ships, navies of other nations, and recreational boaters increases the volume of these wastes by at least tenfold.

The Department of Defense (DOD) has said that there is no suitable alternative to plastic packaging of military rations. Consequently, DOD is under a tight deadline to find a suitable biodegradable alternative. The U.S. Army--in conjunction with USDA and private companies--has implemented a large-scale effort to develop biodegradable polymers to replace petroleum-based plastics for most packaging uses. Many of these polymers are being made from corn, wheat, and potato starch, as well as other biodegradable materials. They are fully degradable but generally cost 2 to 10 times more than petroleum-based plastics. [Douglas Beach (202) 219-0085 and Irshad Ahmed (202) 232-4108]

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Fats and Oils

Industrial rapeseed acreage is down, while crambe acreage has risen 150 percent from last year. Industrial rapeseed and crambe oil derivatives are used in slip agents for plastic films, lubricants, and automatic transmission fluids. A major corporation now markets a biodegradable hydraulic fluid made from canola oil.

Jojoba prices are down, and growers and processors are working to find new uses for the oil. Animal- and plant-based oils are making inroads into surfactant markets. Plus use of soy inks continues to grow.

Biodiesel, which can be made from just about any animal or plant fat or oil, is being commercially produced in Europe, and is being tested by several bus fleets in major cities in the United States as a means of meeting CAAA emission standards. Further testing and certification are needed, but results so far are favorable.

Fats and oils can be used directly in the manufacture of products. For example, soy oil is employed in printing inks as a carrier for pigments and other components. Through a process called saponification, coconut oil and tallow are made into soap. However, for industrial purposes, many fats and oils are broken down into their component fatty acids and further chemically modified (figure 5). (Chemicals made from fats and oils are often called oleochemicals to distinguish them from petrochemicals.)

In 1992, 5.9 billion pounds of fats and oils were used for fatty acids, animal feeds, soaps, resins and plastics, paints and varnishes, lubricants, and other inedible uses. During the last 7 years, these applications have accounted for 27 to 30 percent of total use (table 20).

New Uses Emerging for Industrial Rapeseed and Crambe

Two types of rapeseed are being grown in the United States. Canola is the name of rapeseed varieties that have less than 2 percent erucic acid in their oil, making them suitable for human consumption. Industrial rapeseed, on the other hand, must contain at least 45 percent erucic acid in its oil to meet industrial standards.

Industrial rapeseed has been grown in the Pacific Northwest for over 40 years. Since the mid-1980's, it also has been produced in the Mid-South. Harvested acreage of industrial rapeseed has varied over the last few years, from a high of 19,400 acres in 1987/88 to 9,800 acres in 1992/93 (table 2).

Small amounts of crambe acreage were grown in the United States for research and commercial purposes 20 years ago. In recent years, however, crambe has dramatically resurfaced. In 1990, 2,200 acres were harvested in North Dakota, and planted acreage this year is estimated at 60,000 (table 3). Farmers were paid about 9.5 cents per pound for their 1992 crop, and contracts have been issued this year at 10 cents per pound. A potential area of production is northeastern Colorado, southwestern Nebraska, and northwestern Kansas

Table 2--Rapeseed, acreage planted, harvested, yield, production, and value, 1987-92

Year	Planted	Harvested	Yield	Production	Value
	--1,000 acres--		Bushels per acre	1,000 pounds	Million dollars
1987	20.0	19.4	22.7	21,981	N.A.
1988	13.5	13.1	24.1	15,822	N.A.
1989	14.0	13.6	28.2	19,143	2.01
1990	15.0	14.5	31.2	22,717	2.33
1991 1/	18.2	15.6	20.7	16,146	1.63
1992 2/	12.0	9.8	29.5	14,455	1.45

N.A.= Not available.
1/ Preliminary. 2/ Forecast.

Figure 5

Processing Fats and Oils into Industrial and Consumer Products

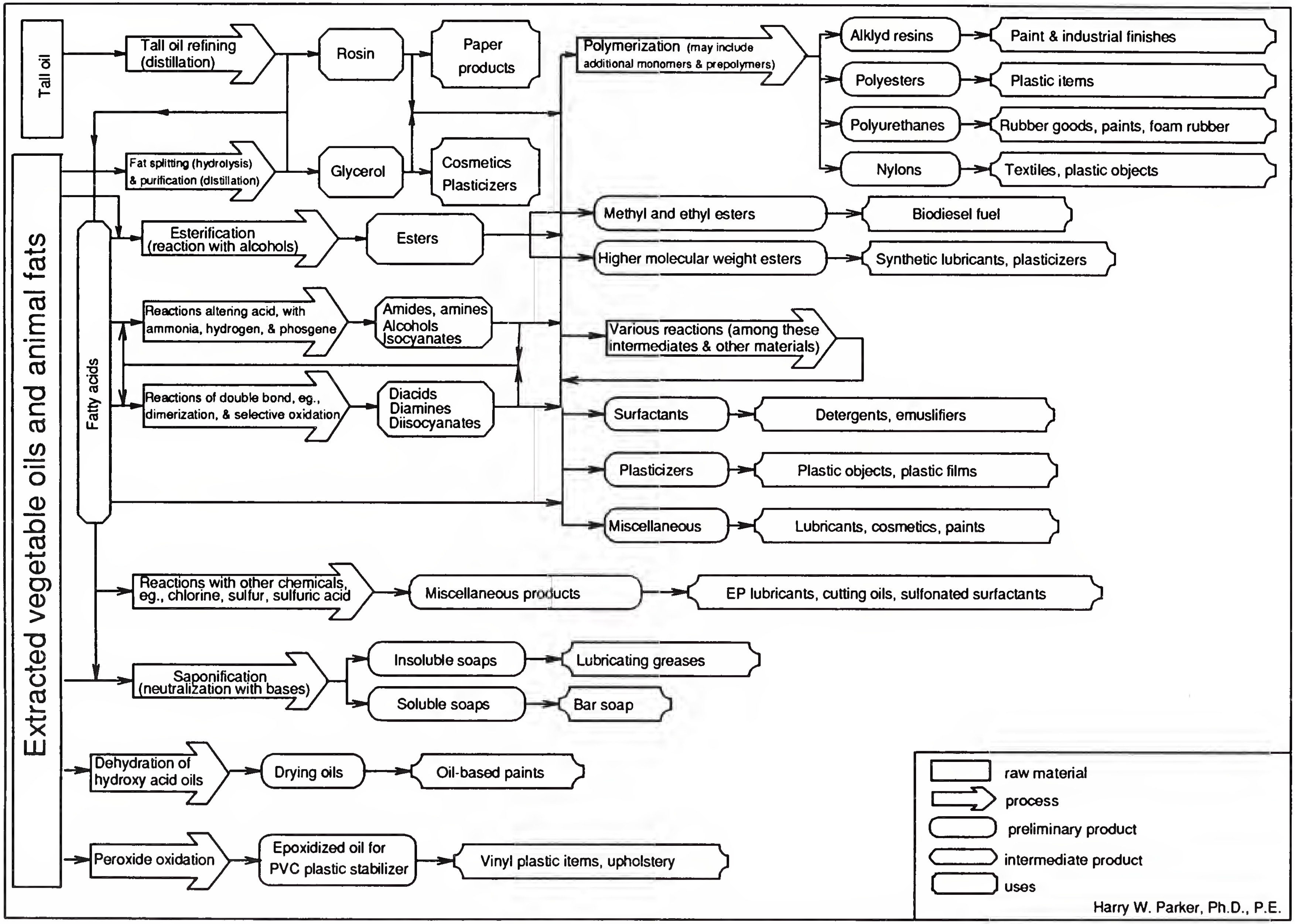


Table 3--Crambe acreage, United States, 1990-93 1/

Year	Area	Yield 2/
	Acres	Pounds/acre
1990	2,200	1,300
1991	4,500	1,338
1992	24,000	1,138
1993	3/ 60,000	N.A.

N.A. = Not available.
1/ Commercial acreage. 2/ North Dakota only. 3/ Estimated planted.
Source: National Sun Industries.

where National Sun Industries has constructed a sunflower crushing plant that is capable of processing both crambe and industrial rapeseed.

In the past, most industrial rapeseed and crambe oils were processed into erucamide. Plastic-film manufacturers have used erucamide for decades in bread wraps and garbage bags. It lubricates the extruding machine during manufacture of thin plastic films. After processing, the erucamide migrates to the surface of the films and keeps them from clinging together.

More recently, erucic acid oils have been showing up as raw materials in a wider array of industrial products. Because they have a high degree of lubricity, rapeseed and crambe oils are used either as direct lubricants or in lubricant formulations. Calgene Chemical (Skokie, IL) has introduced a line of erucic acid esters to the textile and automotive fluids industries. International Lubricants, Inc. (Seattle, WA) markets an automatic transmission fluid (ATF) supplement and a metal cutting oil based on derivatives of rapeseed oil. In independent third-party tests, the ATF fluid supplement decreased wear by more than 50 percent compared to the wear associated with factory-fill ATF fluid. The metal cutting oil lengthens tool life, produces smoother cuts, lasts longer, and is more worker friendly.

In 1991, Mobil Oil began marketing a biodegradable, nontoxic, antiwear hydraulic fluid. The product is composed of 97 percent canola oil and 3 percent other natural materials. It has environmental advantages for machinery used near water, such as hydraulic equipment at barge- and ship-loading docks, and at hydroelectric plants. It is also used in lawnmowers and other equipment on golf courses to prevent killing the grass when hydraulic oil leaks occur. Mobil projects that the U.S. market for biodegradable lubricants could exceed 20 million pounds per year by 1995.

Work continues on additional uses for rapeseed and crambe oils and their derivatives. USDA's Cooperative State Research Service leads the High Erucic Acid Development Effort (HEADE), consisting of ten state organizations (University of Georgia, University of Idaho, University of Illinois, Iowa State University, Kansas Board of Agriculture, Kansas State University, University of Missouri, University of Nebraska, New Mexico State University, and North Dakota State University). Begun in 1986, HEADE's purpose is to expand commercial use of crambe and industrial rapeseed in the United States.

Through HEADE and other USDA programs, extensive research and development has been conducted on the potential uses of these two crops (table 4). For example, erucic acid can be split into brassylic and pelargonic acids. The brassylic acid can be further modified to make nylon-13,13. This nylon offers superior performance characteristics--low moisture absorption, good strength and dimensional stability, and excellent insulating properties.

The commercialization of nylon-13,13 has been hindered by the lack of a reliable supply of domestically produced erucic acid and a cost-effective method of producing brassylic acid from erucic acid. However, North Dakota State University chemists and University of Nebraska chemical engineers have recently developed a new, lower cost and safer catalytic method of making brassylic acid. Nylon-13,13 is presently being tested for the Electric Power Research Institute for use as a cover for underground electrical cables.

Jojoba Prices Down

Jojoba is a perennial evergreen shrub native to the southwestern United States and northwestern Mexico. Some plants bear seed after 3 years, but it takes about 5 years for a plantation to produce enough seed for commercial harvest. The jojoba industry began in the mid-1970's when the oil was touted as a replacement for sperm whale oil. From 1976 to 1983, seed was gathered from wild stands in Arizona and southern California. Since 1984, jojoba has also been harvested from commercial plantations. Production has increased from 12 tons in 1976 to 2,073 tons in 1992 (table 5). Over the past 15 years, jojoba has grown to be an $11 million industry at the farm gate and about $14 million out the processor's door, with at least 70 percent of these revenues derived from exports.

U.S. production is centered in Arizona, with some in California (table 6). From their annual survey of growers, the Jojoba Association reports that 1992/93 production was about 4.1 million pounds. According to the Association, several growers reported stopping their harvest of the 1992/93 crop because seed prices were falling below $1 per pound. If prices do not improve, it is unlikely that the 1993/94 crop will reach current estimates.

In 1992/93, five major U.S. processors purchased over 2.4 million pounds of seed and produced over 96,000 gallons of oil (table 7). Jojoba oil is chemically different from other seed oils. Instead of being a triglyceride, it is made up of liquid wax esters. The cosmetics industry uses more than 90 percent of jojoba oil output and will likely continue as the major industrial consumer over the next decade. According to International Flora Technologies, Ltd., a jojoba processor, this trend is partly due to the cosmetic industry's shift from products of animal origin to materials of botanical origin.

Potential markets include industrial and automotive lubricants, as additives in automatic transmission and differential fluids, for example. However, for jojoba oil to compete in these

Table 4--Potential uses for crambe and industrial rapeseed

Raw material	Intermediate products	Industrial and consumer products
Meal		Livestock protein, protein isolates, fertilizer
Oil	Triglycerides	Pharmaceuticals, lubricants, heat transfer fluids, dielectric fluids, waxes
	Erucic acid	Erucamides (slip agents), plasticizers, amines (surfactants, antistats, flotation agents, corrosion inhibitors)
	Behenic acid	Antifriction coatings, mold release, mixing and processing aids, flow improvers, food itmes
	Erucyl alcohol	Surfactants, slip and coating agents
	Behenyl alcohol	Surfactants, slip and coating agents
	Wax esters	Lubricants, cosmetics, functional fluids
	Fatty acids	Existing C14-C20 fatty acid markets
	Brassylic acid	Nylons, perfumes, plasticizers, polyesters, synthetic lubricants, paints and coatings
	Pelargonic acid	Plasticizers, plastics, coatings, perfumes, cosmetics, flavors, lubricants

Source: Kenneth D. Carlson and Don L. Van Dyne, editors. Industrial Uses for High Erucic Acid Oils from Crambe and Rapeseed. Columbia, MO; University of Missouri, October 1992, p.8.

high-volume, relatively low-value markets, production needs to go up and prices must come down.

Soaps, Detergents, and Surfactants Are Major Outlets

Various fats and oils are used to make soaps, but generally tallow and coconut oil are blended at varying ratios ranging from 85/15 to 45/55. In recent years, palm kernel oil has been substituted for coconut oil because of their relative prices, and palm oil has been suggested as a substitute for tallow. Most soaps are made directly from fats and oils, but they can also be manufactured using fatty acids.

After World War II, detergents replaced many traditional uses of soaps. Surfactants (surface-active agents) are one of the main ingredients in detergents. They lessen the surface tension between oil-loving dirt and other compounds and the water. (Soap is itself a surfactant.) Surfactants also are used heavily by industry. For example, they impart lubricity for mold release, prevent caking of fertilizer salts, emulsify resins and asphalt, disperse and soften pigments, and waterproof and soften leather.

In 1990, the total U.S. market for surfactants was about 3.5 million tons. Industrial uses accounted for the biggest share, followed by laundry detergents, soaps, dishwashing products, shampoos, and other cleaning agents (figure 6). Surfactants are derived both from oleochemicals and petrochemicals (table 8). In 1990, petrochemical-based surfactants accounted for 52 percent of production, while oleo-based had 21 percent and mixed surfacants, 27 percent.

Fatty alcohols, which are surfactant raw materials, can be made from natural and synthetic sources. Oleochemical-based fatty alcohols are often made from tallow and coconut and palm kernel oils. The U.S. market for fatty alcohols used in detergents is dominated by petrochemically derived products. Henkel Corporation, Procter & Gamble, and Sherex produce oleo-derived alcohols.

Table 5--Historical U.S. production of jojoba seed, 1976-92

Year	Production
	Tons 1/
1976	12
1977	16
1978	80
1979	80
1980	160
1981	300
1982	300
1983	400
1984	600
1985	600
1986	820
1987	875
1988	1,500
1989	1,500
1990	1,500
1991	1,755
1992	2,073

1/ Processed seed.

Source: Jojoba Association.

Table 6--U.S. jojoba acreage and production, 1992/93-1993/94 1/

Area 1992/93	Harvested	Not harvested	Total
		--Acres--	
Arizona	7,366	1,360	8,726
California	2,144	995	3,139
Total	9,510	2,355	11,865
Production		1992/93 actual	1993/94 estimated
		--Pounds--	
Beginning stocks		232,050	2,039,438
Production		4,110,503	5,293,000
Yield per acre		354	446
Seed sold		2,303,115	N.A.
Ending stocks 2/		2,039,438	N.A.

N.A. = Not available.

1/ Data covers May 1, 1992-April 1, 1993. 2/ Inventories held by growers.

Source: Jojoba Association Annual Growers Survey.

Table 7--1992/93 jojoba processor activity 1/

Items	Pounds
Carryover inventory, as of May 1, 1992	
Cosmetic grade oil	342,000
Technical grade oil	64,800
Total	406,800
Unprocessed seed	509,896
Seed volume received	
Native stands	
United States	36,372
Mexico	79,809
Plantations	
United States	2,273,447
Mexico	51,102
Total	2,440,730
Oil produced	
Cold-pressed oil	581,200
Solvent-extracted oil	120,000
Total	701,200
Oil sold	
Cosmetic grades	764,400
Technical grades	88,800
Total	853,200
Unsold inventory, as of April 1, 1993	
Cosmetic grade oil	217,600
Technical grade oil	96,000
Total	313,600
Unprocessed seed	1,830,437
Custom-processed seed	676,924

1/ Data covers May 1 ,1992-April 1, 1993.

Source: Jojoba Association Annual Processors Survey.

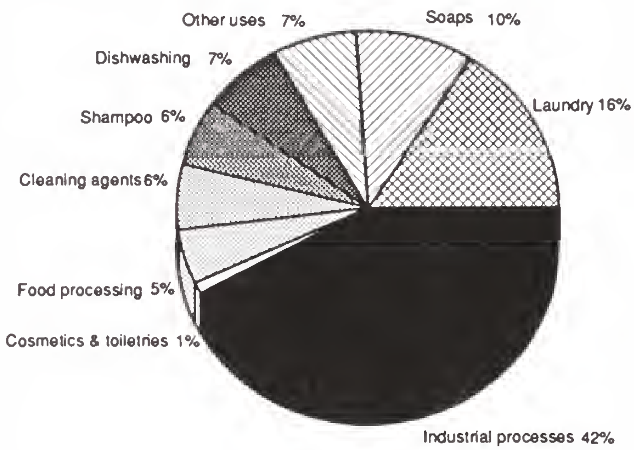
Table 8--U.S. production of surfactants, 1990

Items	Oleo derived	Petroleum derived	Mixed	Total
	--1,000 metric tons--			
Anionic	796.7	962.0	827.3	2,586.0
Nonionic	2.2	708.0	134.4	844.6
Cationic	0.0	287.1	56.4	343.5
Amphoteric	2.0	18.4	0.2	20.6
Total	800.9	1,975.5	1,018.3	3,794.7

Source: Synthetic Organic Chemicals, United States Production and Sales, 1990. United States International Trade Commission, USITC Publication 2470, December 1991, pp. 12-3 to 12-9.

Figure 6

U.S. Utilization of Surfactants by Product Type 1/



1/ Approximately 3.5 million tons of surfactants were consumed.

Source: "Surfactants Aim for Niche Markets," Chemical Engineering, 2 (1992):53-55.

Henkel is a major world producer of coconut and palm kernel oil-based fatty alcohols. The company's traditional surfactants, like lauryl sulfates or alcohol ethoxylates, combine a natural oil-soluble alcohol with a synthetic water-soluble group such as ethoxylate or sulfonate. However, in Henkel's new line of nonionic surfactants--alkyl polyglycosides--the water-soluble group is also based on a natural feedstock, glucose derived from cornstarch. The company sees markets for such new surfactants in cosmetics and personal care products, as well as in laundry detergents, dishwashing liquids, and other cleaning products.

According to a recent report by the Freedonia Group (a Cleveland, OH, market consulting firm), demand for detergent alcohols from coconut, palm, and palm kernel oils will grow at a significantly higher rate than that for petrochemical-based synthetics. The expected market growth is based on claims of superior biodegradability relative to synthetics, increasingly dependable supplies of tropical oils and improved price stability, expectations that long-term oleochemical prices will be more competitive with petrochemical feedstocks, and increasing capacity for oleochemical-derived alcohols production. Demand will depend largely on the commercial success of products made with ingredients perceived as natural, environmentally friendly, and derived from renewable resources.

Color Soy Oil Inks Are Well Established

Inks generally consist of a fine dispersion of pigments or dyes in a solvent vehicle, with or without resins and other additives. Since conventional inks depend heavily on petroleum-based raw materials for most of their components, the ink industry faced problems during the oil shocks of the 1970's, both in terms of cost and availability of raw materials. In response, the American Newspaper Publishers Association (ANPA) developed soybean-oil-based inks for its members, which were first marketed in 1987. Starting with

Castor Oil Prices Forecast To Rebound, Coconut Oil Prices To Dip

According to a time-series forecasting model, castor oil prices are forecast to have declined slightly in May and June and then to bounce back in July and August (table 9). Another model forecast that the price of coconut oil would have risen in May and June, is expected to peak in July, and then slip in August.

The single-equation time-series models used here were estimated with monthly price data from January 1977 to April 1993. Prices from the previous 2 months and monthly seasonal factors are used to explain each month's price. These models capture the historical regularities in these two markets. Forecasts are based solely on historical patterns. These forecasts do not account for random and atypical events, such as political unrest and violent weather. [Ronald Babula (202) 219-0785]

Table 9--Price forecasts for castor and coconut oils, 1993

Month	Castor oil prices	Coconut oil prices
	--Cents/pound--	
1993: 1/		
April	32.0	23.3
May	31.8	23.7
June	30.6	25.5
July	31.5	26.1
August	33.5	25.4

1/ April actual, May-August forecast.

only six newspapers, color soy ink is now used by half of the nation's 9,100 newspapers that use color inks, including 75 percent of the 1,700 U.S. dailies.

Color soy inks have been widely adopted because of their superior performance--brighter colors and more printed pages per volume of ink used--despite their slightly higher price. Color ink prices are based primarily on the cost of the pigments. In contrast, the price of the vehicle oil strongly influences the price of black printing inks. Thus, black soy inks have had a hard time being cost competitive when refined soybean oil is generally more expensive than petroleum-based mineral oil.

According to ANPA, soy oil could replace 75 percent of the 311 million pounds of oil used annually to formulate newspaper inks. As formulas have improved, many companies are beginning to produce and market soy oil inks. As of March 1992, 40 different ink producers had been licensed by ANPA to produce soy inks.

Researchers at USDA's National Center for Agricultural Utilization Research (Peoria, IL) have patented a line of soy inks for use by newspaper publishers. The inks contain no petrochemical compounds (except for pigments), provide a wide range of viscosities, and are more cost competitive with petroleum-based inks.

Newspaper inks are only one of the potential markets for soy oil. In 1990, all printing inks had an estimated combined market size of 3.5 million tons and a value of $200 million. Newspapers used about 7 percent of the ink manufactured in the United States in 1990, while commercial printers used 19 percent, and magazines used 28 percent (figure 7).

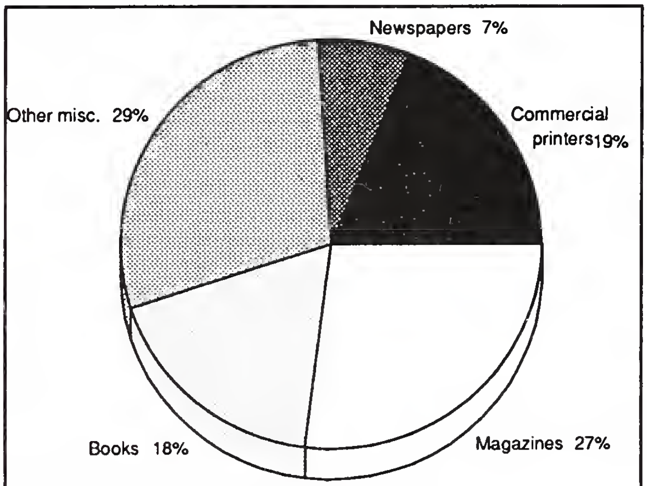
Not only does the volume of soybean oil in ink vary from one manufacturer to another, but it also varies depending on whether the ink is used for newspapers (over 50 percent soy oil), sheet-fed printing (20 to 40 percent), magazines (10 to 15 percent), or business forms (40 percent).

Use of soy inks in other printing categories is showing great promise. One of the most important breakthroughs in soy ink formulations--inks for sheet-fed presses--is responsible for opening up the large commercial printing market to soy inks, particularly for color printing. For example, Alden and Ott (Arlington Heights, IL) has a heat-set ink--available in all four process colors (black, blue, red, and yellow)--containing 12 percent soy oil.

The fundamental problem with soy inks for sheet-fed presses has been its slow drying time compared with mineral oil-based conventional inks that dry in 20 to 30 percent of soy-ink drying time. Although newer soy ink formulations produced for sheet-fed presses dry better than their predecessors, it still takes almost twice as long as for conventional inks. Efforts are underway to further improve soy oil inks' drying properties.

Figure 7

U.S. Ink Markets by Application Type, 1990 1/



1/ Approximately 3.5 million tons of printing inks were used

Sources: American Ink Maker, November 1991; American Soybean Association, St. Louis, MO, March 1992.

Another development is in the formulation of heat-set soy inks for magazine and periodical publishers. Although available since 1989, heat-set soy inks have yet to make a mark in the magazine market. In a heat-set printing process, the printed paper is dried in an oven where the mineral oil portion of the vehicle is quickly evaporated. Because soy inks dry by oxidation, current heat-set formulations take over 2 hours to dry in the same oven that dries conventional inks in 15 to 30 minutes.

In order to improve the drying time and the overall quality of heat-set soy inks, new formulations containing resins and special solvents have been introduced. However, price is a problem. Since resins are expensive, costing as much as $2.00 to $3.00 per pound, even a small percentage incorporated into a formulation pushes the cost of soy inks beyond a competitive price range. Even so, formulas are being improved, and many companies are beginning to produce and market heat-set soy inks.

Why do printers use soy-based inks?

- Improved press operation and clean up.

- Lower worker exposure to harsh petrochemicals.

- Reduced emissions of volatile organic compounds. VOC's are one of the principal components in chemical reactions in the air that form ground-level ozone, a pollutant in the lower atmosphere that can cause respiratory problems. Compared to petroleum-based inks that have VOC ratings of 25 to 40 percent, all soy ink manufacturers report VOC ratings of less than 10 percent. Most color soy inks are in the 2- to 4-percent range.

- Great marketing benefits--highlighting the environmental advantages of soy inks.

Soy inks also have an advantage in recycling paper. When paper is recycled, the pulp must de-inked. Researchers at Western Michigan University have found that soy inks de-ink faster and more cleanly than conventional petroleum-based inks. The soy oil releases more easily from the paper, resulting in longer fibers and a higher quality of recycled paper.

Biodiesel Is a Reality

Biodiesel, a substitute for petroleum-based diesel fuel, can be made from vegetable oils, animal fats, and waste grease. It can be used in unmodified diesel engines in either pure form (i.e., neat) or blended with petroleum-based diesel. Biodiesel has been commercially produced in Western Europe for the last 3 years. Biodiesel's environmental and technical qualities have pushed it closer to commercialization in the United States.

Transesterification produces biodiesel. An alcohol is mixed with a catalyst that is then blended with the vegetable oil or animal fat. Each 100 gallons of vegetable oil combined with 26 gallons of methanol and 8 pounds of sodium hydroxide will make about 100 gallons of biodiesel, about 8 gallons of glycerine, and some mixed fatty acids.

Biodiesel was first commercially made in Austria in 1990 with government support. Recent reforms in the European Community's Common Agricultural Policy and other incentives provided by the individual EC members are likely to encourage increased output of crops used to make the fuel. Methyl ester, the most common type of biodiesel in Europe, is made primarily with rapeseed and sunflowers. Both blended and unblended biodiesel is burned in Europe.

Biodiesel production and use is well advanced in France, Italy, and Germany. The EC now can produce 150,000 to 200,000 metric tons per year of biodiesel. Additional plants are planned that could raise capacity to over 600,000 tons per year. Production of biodiesel in the EC has been estimated at 80,000 tons in 1992.

European government policies are encouraging biodiesel production and use. The governments are using biodiesel as an outlet for agricultural products, a source of rural employment, a substitute for petroleum imports, and to reduce most "greenhouse gas" emissions. However, a recent EC study estimated that the cost of biodiesel exceeds the cost of conventional diesel by an estimated 0.19 to 0.21 ECU per liter (86 to 95 cents per gallon). Still, recent and proposed policy changes of the EC and its member countries can alter the costs considerably:

- ***Member countries' tax policies.*** Italy and France, for example, exempt biofuels from taxes levied on hydrocarbon-based fuels. This is a big break, since about 50 percent of the French fuel-pump price is tax.

- ***CAP reform.*** Now, most producers must set aside a portion of their cropland to be eligible for a support payment. However, farmers may plant on set-aside land certain crops for industrial uses. This policy could provide an incentive for the production of oilseeds for biodiesel. In 1993, total EC area sown to rapeseed for industrial purposes on set-aside land is estimated to be 250,000 hectares.

- ***EC tax policy.*** The EC has proposed permitting its members to give a 90-percent fuel-tax break to biofuels. In addition, the EC has proposed taxing carbon dioxide emissions and the energy content of fuels. Renewable sources of energy would be exempt. Member countries are far from an accord on this tax.

- ***Other programs.*** These include research and development funding for industrial uses of agricultural materials, assistance for developing improved varieties, and funding for pilot projects testing biodiesel's viability for public transport.

Biodiesel production and use should grow in the EC over the next several years. But this has also come up in the international trade talks. The "Blair House" agreement between the United States and the EC limits the set-aside area planted to industrial oilseeds to the equivalent of 1 million tons of

soybean meal--approximately 2.3 million tons of rapeseed. That would be about 900,000 tons of biodiesel, far above current or planned capacity.

U.S. Use of Biodiesel Depends on Testing, Certification

Several advances are needed before biodiesel is commercialized in the United States: exhaust emissions must be documented using EPA's protocol, the fuel must be certified for use in diesel engines by the American Society for Testing and Materials (ASTM), and the fuel must be accepted by diesel engine manufacturers--to maintain engine guarantees--and the private sector. Coordinated efforts by industry, government, trade associations, and businesses are making rapid progress in each of these areas.

Current testing and research centers around the emissions and long term durability of engines fueled with biodiesel. Groups involved with conducting EPA Transient Cycle engine tests are the National Institute for Petroleum Energy Research (NIPER, Bartlesville, OK), the Southwest Research Institute (SwRI, San Antonio, TX), ORTech (British Columbia, Canada), and FEV of America (Detroit, MI).

NIPER will be starting engine durability tests on engines commonly found in city bus fleets, pickups, and tractors. Testing, which was funded by the National SoyDiesel Development Board (NSDB) and DOE, began in May. SwRI will begin testing SoyDiesel's (biodiesel from soybean oil) effects on engine wear and emissions on another engine that is commonly used in bus fleets in an EPA-approved laboratory. This research was funded by the NSDB and the AARC Center.

Preliminary testing on biodiesel blends was recently completed by ORTech. They showed that a 80/20 blend of clean diesel/SoyDiesel will be capable of meeting all CAAA guidelines for 1995. ORTech will continue their work with biodiesel to determine if retarding engine timing will allow for a reduction in NOx emissions. Results should be available by late summer.

Blend and emissions testing at the University of Missouri show that emissions are influenced by the different design variables of an engine. So each engine on the market today will have different emission reductions with biodiesel. The research also shows that, in general, a diesel/biodiesel blend will reduce harmful emissions and help meet future environmental regulations. FEV of America will begin testing engines this fall. Limited testing of dual-fueled engines has also taken place. Detroit Diesel has been working with a combination of biodiesel and compressed natural gas.

Fuel certification by ASTM could be in one or more of the following categories: as a fuel substantially similar to petroleum-based diesel fuel, as an additive, and as a separate ASTM fuel standard. Although a dedicated biodiesel plant has yet to be built in the United States, biodiesel is currently being marketed. In August 1992, Procter & Gamble agreed to produce up to 15 million gallons of biodiesel for Interchem Industries, Inc. (Kansas City, KS). The biodiesel will be produced from soybean oil and/or animal fats.

Biodiesel sales have been made to bus fleets and maintenance vehicles at airports. Preliminary results from limited bus-fleet tests have prompted more extended studies in some cities, including St. Louis, MO. In Gardena, CA, engine durability and emissions will be examined for city buses to see if California's clean air guidelines can be met with biodiesel. [Lewrene Glaser (202) 219-0085, Irshad Ahmed (202) 232-4108, Donald Van Dyne (314) 882-4512, and Mary Anne Normile (202) 219-0620]

Supercetane Increases Diesel's Punch

Supercetane, derived from plant and tree oils by high-pressure hydrotreating, is a fuel additive used for increasing diesel's cetane value. The cetane value measures the fuel's ability to self-ignite, like the octane value for gasoline. Supercetane derived from plant oils has a cetane value of 90 to 100, and from tree oils a value of 70 to 75. The cetane value of #2 diesel is about 45, while biodiesel has a value of 50 to 55. The minimum cetane value for a fuel used in a U.S. diesel engine is 40. Currently, most petroleum diesel fuel contains synthetic additives to increase its cetane value above 40.

Supercetane is cost-competitive with synthetic cetane enhancers and does not have the diminishing marginal effectiveness of synthetics. Supercetane appears to be more effective than synthetic additives on low cetane-base fuels. The only problem with supercetane is that it has a high pour point (or freezing point); this can be alleviated when the additive is diluted in conventional fuel.

Canola, soybean, rapeseed, palm, sunflower, coconut, and tall oil have all been processed into supercetane. Tall oil, a byproduct of the kraft paper-making process, appears to be the most cost-competitive. Although the tall-oil converted supercetane has a lower cetane value (around 70), tall oil is inexpensive enough to make it an economically viable cetane enhancer.

Production would use petroleum refineries' hydrotreating facilities. Since there are several underutilized facilities in North America, only minimal capital investments would be necessary to begin production. Currently, Arbokem Inc. (Vancouver, British Columbia) is evaluating the costs of building a demonstration plant. [David Pace (202) 219-0085]

Natural Fibers

Kenaf, a tropical fiber crop, is now being commercially grown in the United States. Over 4,300 acres have been planted this year in the South and West. Kenaf is used for

packing materials, bond paper, horticultural mulches, potting mixes, seeding mats, animal litter and bedding, and oil absorbents. Potentially, it could move into the newsprint and paperboard markets.

Erosion-control products are promising to increase the demand for natural fibers in general. In addition, some countries are increasingly turning to nonwood fibers for paper as local supplies of trees become tighter. Most traditional uses of these fibers--cordage and sacking--have been declining due to the increased use of synthetic fibers and changes in transporting and storing grain. This issue covers kenaf, jute, abaca, hemp, sisal, coir, and milkweed.

In the United States, natural fibers occupy various niche markets, including specialty papers, some cordage uses, horticultural mulches and mixes, and down comforters (figure 8). As environmental concerns heighten, natural fibers are finding their way into new markets, such as manufactured erosion-control products.

Jute, hemp, sisal, abaca, and coir fibers and products are imported. Kenaf and milkweed are produced and processed in this country. (Wood fibers are discussed in the Forest Products Section. Information on cotton and wool is available from *Cotton and Wool Situation and Outlook*; to order call 1-800-999-6779.)

Throughout the world, natural fibers are primarily used for rope, twine, sacking, and mats. Jute, kenaf, and hemp yield bast (stem) fibers that are used for rope, sacking, coarse fabrics (burlap), and mats. Depending on the application, these bast fibers may be substitutes for each other. Sisal is used for twine. Coir, the fiber from coconut husks, is used for mats, brushes, and brooms.

In developed countries, two factors have led to the decline of natural fibers in cordage and sacking. First, plastics and metals have made large inroads into the coarse textile and cordage markets. Second, the shift to bulk grain transport and storage has eliminated much of the need for sacking materials.

Paper is another major use of natural fibers around the world. In countries that are short of wood, paper and paperboard can be made from agricultural residues, natural growing plants, and fiber crops (table 10). In 1990, 21 countries, including China and India, depended on nonwood fibers for more than 50 percent of pulp production, according to Joseph E. Atchison, an expert in the use of nonwood fibers for paper production.

In the United States, flax is the most extensively used nonwood fiber employed in papermaking, except for cotton. The decorticated straw, called flax tow, from oilseed flax varieties--grown for linseed oil and meal in many parts of North America--is the primary raw material used by two U.S. manufacturers for cigarette paper. Byproducts of textile flax varieties--which are grown for their linen fibers--are imported to enhance the properties of cigarette paper and for use in currency paper. Standard U.S. currency paper is 80 percent cotton and 20 percent flax.

Table 10--Nonwood fibers that can be used to make paper

Fiber type	Example
Agricultural residues	Sugar cane bagasse
	Sorghum
	Corn stalks
	Cotton stalks
	Rice straw
	Cereal straws
Natural-growing plants	Bamboo
	Esparto
	Elephant grass
	Reeds
	Sabai grass
	Johnson grass
	Papyrus
Nonwoody fiber crops	
Bast (stem) fibers	Jute
	Ramie
	Crotalaria (sunn hemp)
	Hemp
	Kenaf
	Flax tow and byproducts
	Old rope or rags made from bast fibers
Leaf fibers	Abaca (manila hemp)
	Sisal
	Henequen
Seed hair fibers	Cotton fiber
	Cotton linters
	Cotton rags and textile waste

Source: Joseph E. Atchison and John N. McGovern. "History of Paper and the Importance of Non-Wood Plant Fibers." Pulp and Manufacture, Third Edition: Volume 3, Secondary Fibers and Non-Wood Pulping. Joint Textbook Committee of the Paper Industry, 1987, p. 3.

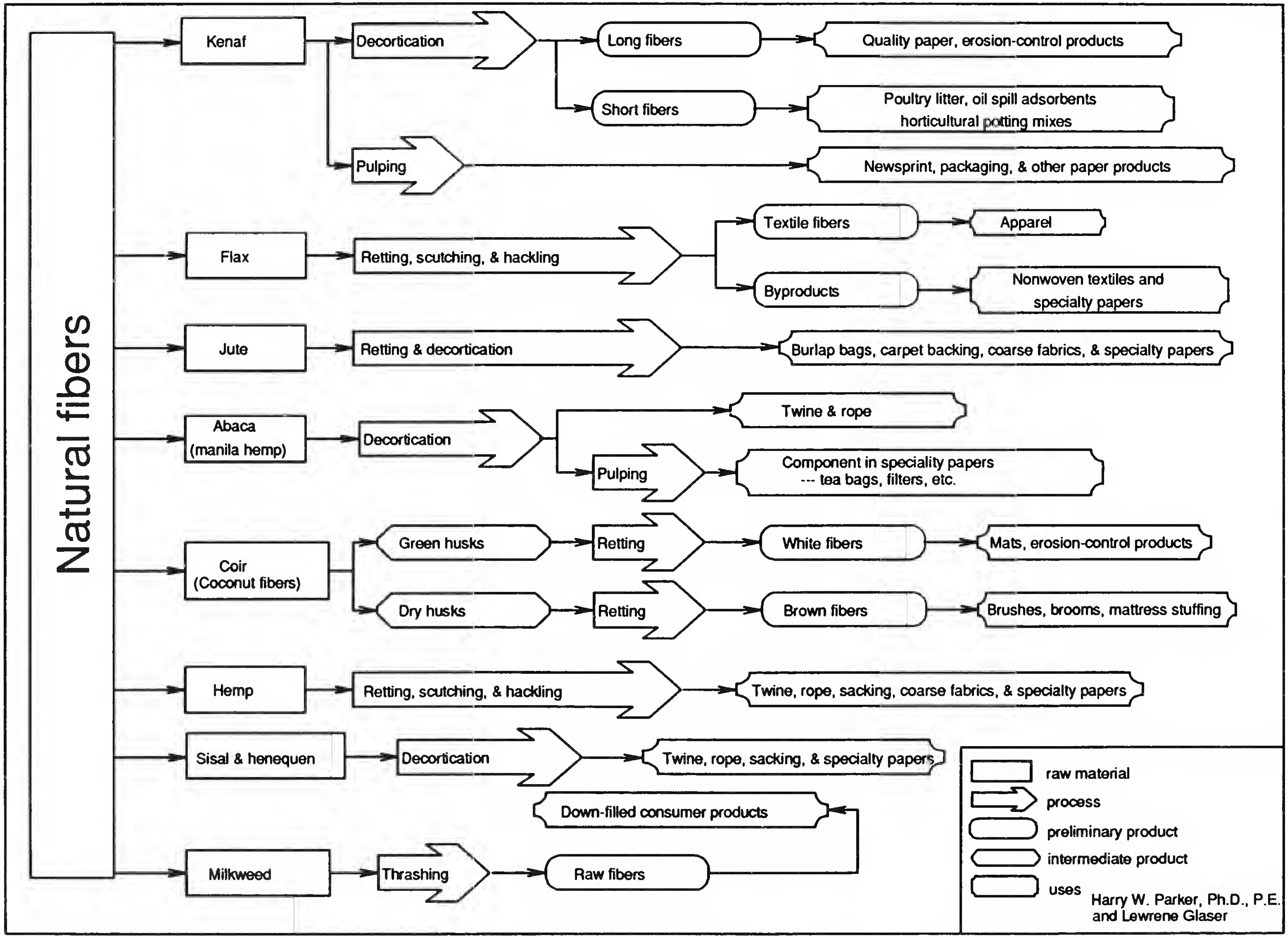
Nonwood fibers have a vast potential for use in many new and expanded product areas. However, each fiber has intrinsic characteristics that make them more or less suitable for various applications. A large-scale shift from wood to nonwood fibers, as some have advocated, would require significant research, development, retooling, and industry restructuring.

Kenaf: A New U.S. Fiber Crop

Kenaf is an annual crop native to the tropics that has traditionally been used as a source of bast fibers. India, China, Taiwan, the former Soviet Union, Iran, Mozambique, Cote d'Ivorie, Nigeria, Guatemala, Thailand, and El Salvador have

Figure 8

Processing Natural Fibers into Industrial and Consumer Products



all grown kenaf in commercial quantities in recent years. About 5,000 acres will be grown in Europe during 1993, mostly in Italy.

Kenaf is a new commercial crop in the United States. Grown mostly in southern and western States, plants can reach 10 to 16 feet in height after a 5-month growing season. In 1992, 1,391 acres were harvested and 4,345 acres are being planted this year for fiber, seed, and forage production (table 11). Another 2,800 acres, planted in Mississippi in 1992, have just been harvested. Yields in 1992 were estimated at 6 tons per acre in Louisiana and 7 tons in California and Texas.

Like flax, jute, and hemp, kenaf stems consist of an outer bark of bast fibers and an inner core of shorter fibers. In kenaf, the bast fibers make up about 30 to 40 percent of the stem, on a dry-weight basis, and the shorter core fibers make up the remainder.

Four companies are now operating fiber separation facilities in the United States. Kenaf International, Ltd. (McAllen, TX) sells bast to companies for making cordage, twine, and bond paper and sells the core for use in soil-less potting mixes, animal litter and bedding, and feed products.

Natural Fibers of Louisiana, Inc. (Jeanerette, LA) sells horticultural mulches, potting soils, packing materials, burlap, and bedding materials. The company also markets a line of oil and chemical absorbent products--compressed bags, burlap pillows, land booms, flotation booms, and loose material--that can be used to clean up land or water-based spills. These kenaf-based products are now listed in the General Service Administration's Federal Supply Schedule, thus allowing Federal agencies to purchase these materials.

Agro-Fibers, Inc. (Angiola, CA) sells bast to manufacturers for packing materials and high-grade pulp and core for animal bedding and as an ingredient in potting mixes. The company uses bast fibers in the production of nonwoven mats that are impregnated with grass seed and polymers for use in landscaping. A wildflower mat and an erosion-control blanket will be introduced later this year or next.

Table 11--Kenaf acreage, United States, 1992-93 1/

State	1992	1993
	--Acres--	
California	560	560
Georgia	--	130
Louisiana	300	260
Mississippi	2,800	2,000
New Mexico	50	205
Texas	481	1,200
Other 2/	--	20
Total	4,191	4,375

-- = Not applicable.
1/ Data for 1992 represents harvested acreage. Data for 1993 represents planted or projected acreage, including acreage for fiber, seed, and forage production. 2/ Arkansas, Florida, and Hawaii.

The Mississippi Delta Fiber Cooperative (Charleston, MS) is replacing a major section of their separation system with modified cotton-ginning equipment. The plant is expected to be up and operational during June. The cooperative is planning to sell bast to specialty pulp and nonwoven manufacturers and core for animal bedding and absorbents.

Both researchers and businesses point to paper and paperboard as major markets for kenaf. Several large-scale demonstration runs have shown that kenaf produced excellent newsprint. USDA research indicates that 25 percent kenaf pulp blended with 75 percent recycled newsprint yielded newsprint with acceptable properties. Successful experiments also have produced bond, surface-sized, and coated papers from kenaf. The bast fiber also has a number of potential applications where high strength and low permeability is required, such as package and wrapping papers.

KP Products Incorporated (Albuquerque, NM) has set up a business to manufacture and sell a high-grade premium printing paper made with kenaf bast fibers. Gridcore Systems International (Carlsbad, CA) is planning to use kenaf fibers in their structural composite panels (see box in Forest Products Section). Kenaf International plans to construct a paper mill to manufacture newsprint made of the entire kenaf stalk combined with recycled fibers.

In the United States today, nonwood fibers are mainly used in specialty applications, including cotton fiber for currency paper, flax tow for cigarette paper, bagasse for insulating board, and abaca for porous-plug wrap paper (the paper that surrounds and holds cigarette filters), tea bags, filter papers, and sausage casings. Wood fibers have made inroads into cigarette paper markets, thus affecting competing fibers.

Another potential market is nonwoven mats and other products. Kenaf and other natural fibers can be used to make nonwoven materials, such as interior automotive paneling and landscaping mats. The technology is similar to that used to make disposable diapers and other textiles.

Milkweed Reaches Niche Markets

Milkweed is being grown in Nebraska for its floss, the hairy fibers attached to the seed. Natural Fibers Corporation (Ogallala, NE) was formed in 1987 to commercialize products using milkweed floss. Milkweed is a perennial; commercial stands should last 5 to 10 years. A modified self-propelled corn picker is used to harvest milkweed pods. After harvest, the pods are cracked open and the floss is dried and separated.

Milkweed floss was used in life jackets during World War II. It has about the same density, slightly higher insulating capacity, and better durability than high-quality goose or duck down. The fibers are water resistant and nonallergenic. These characteristics--combined with the light weight of the floss--make it a good candidate for filler in comforters, sleeping bags, and insulated clothing. Natural Fibers Corpo-

Kenaf Forage a Possibility

In addition to other possible uses, kenaf also has the potential to become a forage crop. Researchers from the Agricultural Research Service laboratory in El Reno, OK, and Oklahoma State University (OSU) began studying kenaf as a potential forage in 1989. Although a long way from commercial production, kenaf forage is an example of a new use in the beginning stages of research and development and is illustrative of how new crops are developed.

In the Southern Plains, the predominant farm enterprise is winter wheat and stocker cattle. The wheat is harvested in early June and the land traditionally remains idle until wheat is planted in September. Thus, the soil is left exposed during the hot dry summer months and wind erosion may be considerable. Livestock graze on warm season grasses from May through August, but additional forage is needed in the fall.

Having access to forage on farm is a major benefit to farmers in the Southern Plains, and kenaf's short growing period for forage offers an advantage over other annual forages, like sorghum, cow peas, and mungbeans. The results of production and feeding trials lend support to the idea of using immature kenaf as a quality forage. In addition, an enterprise budget developed by OSU researchers indicated that the addition of kenaf to the wheat-stocker enterprise could increase net returns by $16.24 per acre.

Kenaf is being analyzed as a potential livestock forage because of its high protein content, ability to withstand heat and drought, multiple harvesting times, and relatively high yields. Although some farmers have already begun to experiment with kenaf as a forage, widespread commercialization must wait for more precise production and use information including:

- Selection and development of forage varieties,
- Identification of proper planting conditions for forage,
- Development of optimal cultural practices,
- Determination of the effect of forage production on soil moisture,
- Determination of the optimal harvesting time,
- Identification of the best harvesting methods, and
- Identification of feeding methods that may improve palatability and digestibility.

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ration is manufacturing comforters filled with a mixture of milkweed floss and goose down. Virtually all goose and duck down is imported.

The company is developing markets that match its 40,000-pound production capacity. Low yields are an obstacle to developing milkweed as a commercial crop for high-volume uses. Company and university researchers are working together to overcome the technical barriers to milkweed production and use, including yield improvement and product analysis.

As market demand, yields, and production increase, milkweed floss could be competitive in higher volume, lower value markets, such as nonwoven textiles and absorbent pulp products. Because the floss absorbs 75 times its weight in liquid once stripped of its wax coating, possible uses include disposable diapers and other super-absorbent products.

Many Natural Fibers Are Produced in Tropical Countries

Jute is a tropical crop grown mainly in India and Bangladesh. The plants are annuals, which take 3 to 5 months to mature. At harvest, stems are cut and taken to retting pools or ditches. Retting loosens the bast fibers from the inner part of the stem. Retting can last 1 to 4 weeks, depending on conditions. The bast fibers are then separated from the rest of the stem, usually manually, and dried.

According to a November 1992 report of the Intergovernmental Group on Jute, Kenaf, and Allied Fibers (an entity within the U.N. Food and Agriculture Organization [FAO]), the percentage of jute products traded internationally in 1990 was about 27 percent of estimated total use, compared to 42 percent in the mid-1960's. This decline resulted from increased use of jute in producing countries and a decrease in overall utilization. Between 1980 and 1990, imports of jute

products into developed countries fell by 23 percent. Some rise in imports of yarn was offset by declines in imports of sacking, hessian cloth, and other products.

Abaca (manila hemp) is obtained from the leafstalks of a member of the banana family. A few stalks may be cut from each plant every 4 months for several years. The fibers are stripped from the leaves either by hand or mechanically. The major producing countries are the Philippines and Ecuador, with the Philippines accounting for nearly 85 percent of world output. In a reversal of historic trends, Philippine abaca has been more expensive than Ecuadorian in the past few years due to unstable socio-political conditions, recent natural disasters, and poor climatic conditions.

Like jute and hemp, abaca was widely used for cordage. However, following the development of man-made fibers in the mid-1960's, demand for abaca cordage declined markedly. FAO's Intergovernmental Group on Hard Fibers estimates cordage uses at less than 20 percent of world abaca output. Today, abaca fibers are mainly used in the manufacture of high quality specialty papers, such as porous-plug wrap paper, tea bags, stencil-base tissue, meat sausage casings, dust filters, and a number of other applications. The variability of quality supplies and periodic high prices have hampered abaca's use in other grades of paper. Specialty paper manufacturers have undertaken the search for alternative materials, such as sisal.

Sisal is a perennial crop grown in Brazil, Kenya, Tanzania, Madagascar, Haiti and other tropical countries. A related plant, henequen is grown in Mexico and in other central American countries. The term sisal generally refers to both fibers as they are used for the same end-products. Leaves are harvested at 6- to 12-month intervals, and the fibers are stripped from the leaves and dried. Sisal is primarily used as a bailing twine. Since the mid-1960's, however, polypropylene twines have progressively taken over the market. Correspondingly, the area under sisal cultivation has fallen. Because of lower prices, growers have converted their fields to pasture or abandoned them.

Coir is the fiber obtained from the husk of coconuts. Its outstanding characteristic is its resistance to rot. Although coconut is grown in a number of countries, commercial coir production in centered in India and Sri Lanka. Immature and mature husks are retted and the fibers separated by hand or mechanically to obtain white (yarn) fiber and brown (bristle and mattress) fiber. Coir yarn is now used mainly for the manufacture of floor coverings, such as door mats, matting, and rugs. Synthetic fibers now dominate traditional cordage markets. Bristle fibers are primarily used in brushes and brooms.

Hemp, which is also called common hemp or marijuana, is an annual that can be grown in both temperate and tropical climates. Like jute, the stalks must be retted after harvest to separate the bast fibers from the rest of the stem. This can be accomplished by water retting in ponds or by dew retting--leaving the stalks in the field for a period of time.

Very small amounts of hemp fiber are imported into this country for use in rope, twine, and other cordage products. A new use under development is fiberboard. C&S Specialty Builder's Supply Inc. (Harrisburg, OR) was incorporated in 1991 specifically to reestablish the use of hemp for industrial purposes. C&S is developing straw/hemp-based medium density fiberboard. The company plans to import the hemp fiber from China. Plant breeders in various parts of the world are reportedly developing varieties that are low in psychoactive compounds. Worldwide, hemp is used for cordage and cigarette paper.

Erosion-Control Products Open New Markets for Natural Fibers

Erosion-control systems are a new product area for natural fibers that have the potential for fast market growth. For civil engineers and landscaping firms, the tools and materials for erosion control have been around for quite awhile, but it is only in the last 8 to 10 years that manufactured erosion-control products have become available.

According to the Industrial Fabrics Association International (IFAI), the erosion-control market can be divided into two broad categories. Synthetic erosion-control materials, including woven plastic fabrics and mats, are used in applications that are meant to last, such as ditch liners and drainage systems. Organic erosion-control materials--including natural fiber mulches, meshes, and mats--offer temporary soil stabilization and vegetative stand establishment.

IFAI estimates that the erosion-control market is growing at an annual rate of 10 to 15 percent. Organic erosion-control systems are estimated to consume 35 to 40 million square yards of material, while synthetic systems use 20 to 35 million square yards. Natural fibers used for erosion control--such as kenaf, jute, and coir--have advantages, according to the IFAI. They generally cost less, hold moisture better, and are easier to sell and promote when compared to synthetic materials. Also, when the fibers decompose, they add organic matter and nutrients to the soil.

Several companies across the country are using natural fibers in erosion-control and nursery applications. For example, Belton Industries, Inc. (Atlanta, GA) offers a range of coir-based meshes and fabrics for soil stabilization, reinforcement, and landscaping. B&M Packaging Co., Inc. (Charlotte, NC) sells jute mesh for erosion control in landscaping applications. [Lewrene Glaser (202) 219-0085]

Animal Products

According to industry estimates, the value of the beef-byproduct industry is $3 billion a year, with most of that going for industrial uses. In 1992, almost 5.8 billion pounds of inedible tallow was produced in the United States--half was exported. During 1990-92, U.S. production of inedible rendered products rose very slightly. Domestic use slipped

over 12 percent, while exports rose nearly 13 percent. That partly reflects a switch by U.S. consumers to liquid soap from bar soap.

During 1990-92, poultry byproducts processed in the United States increased almost 21 percent. Most went to the domestic feed industry.

In 1993, at least seven plants are using cheese whey to produce ethanol. They have a combined annual capacity to make 7.5 million gallons of ethanol. Wash water solids (WWS), another waste product of the cheese industry, is showing promise as a feed.

Use of animal products in pharmaceuticals is on the upswing. And use of genetically engineered animals for human medical products is just beginning. Use of manure to make methane as an alternative energy source is also being evaluated. These topics will be covered in the December issue. See figure 9 for a description of how animal products move from the farmgate to the industrial marketplace.

U.S. Processing of Hides Is Rebounding

In 1989, about 70 percent of U.S. cattle hides were exported for processing. That's because processing hides with traditional techniques domestically was very costly. Those techniques generated hazardous waste products with high disposal costs. As new, more environmentally friendly technologies have been developed, domestic hide processing in the United States has begun to rebound.

By 1992, domestic processing increased to about 35 percent. Through the first quarter of 1993, the share processed domestically increased from 40 to 46 percent. Cattle hide exports in 1992 were slightly over 19.1 million pounds valued at $1.04 billion.

Hides come from cattle, hogs, horses, goats, and sheep, as well as other more unusual animals including deer, kangaroo, buffalo, dog, salmon, seal, walrus, shark, porpoise, whale, sturgeon, alligator, crocodile, and lizard. The estimated value of the hide from an average beef steer in 1992 was $43.08. Value of other byproducts included: $2.16 for edible tallow, $8.04 for inedible tallow, and $18.60 for variety meats. Hides account for most of the total byproduct value.

Hides are used in making leather, as a base for many ointments, and as an insulation material. Ten years ago, about 70 percent of animal hides were used in making shoes in the United States; this has decreased to about 50 percent today. Leather for automotive upholstery now accounts for about 25 percent of animal-hide use. Hair from the hide can be used to make rug pads and high-quality brushes. Hides are also a source of gelatin.

Domestic Inedible Uses of Rendered Products Declines

Edible animal fats may be produced only from edible carcass parts maintained under approved USDA conditions. The beef and pork fats in margarine are two examples of how edible fats are used. All other fats are classified as inedible--not for human consumption. In 1992, almost 5.8 billion pounds of inedible tallow were produced in the United States, with about 2.3 billion pounds being exported (table 12). An additional 2.5 billion pounds of lard and edible tallow were produced in the United States.

Almost 5 billion pounds of edible and inedible tallow and lard were consumed domestically, with the largest single use as an ingredient in livestock and poultry feeds. However, tallows and fats are used as feedstocks in many industrial oils and lubricants. Specifically, they are used for tanning, soap, and to produce glycerine used in cosmetics.

The domestic consumption of inedible tallow for soap was 398.4 million pounds in 1989/90 (table 24). By 1992, consumption had decreased to 334.4 million, or over 15 percent. This reflects consumers shifting from bar to liquid soap, which is made from plant, rather than animal products.

Domestic use in lubricants slipped 42 percent during the same period. However, feed use rose more than 11 percent between 1991 and 1992. Use of lard for inedible purposes rose to 134.6 million pounds, up nearly 70 percent from a year earlier (table 25).

Fatty acids from animals are being used in increasing quantities in a variety of products, including abrasives, shaving cream, asphalt tile, lubricants, candles, caulking compounds, cement additives, cleaners, cosmetics, deodorants, paints, polishes, perfumes, plastics, printing inks, synthetic rubber, and water-repellent compounds.

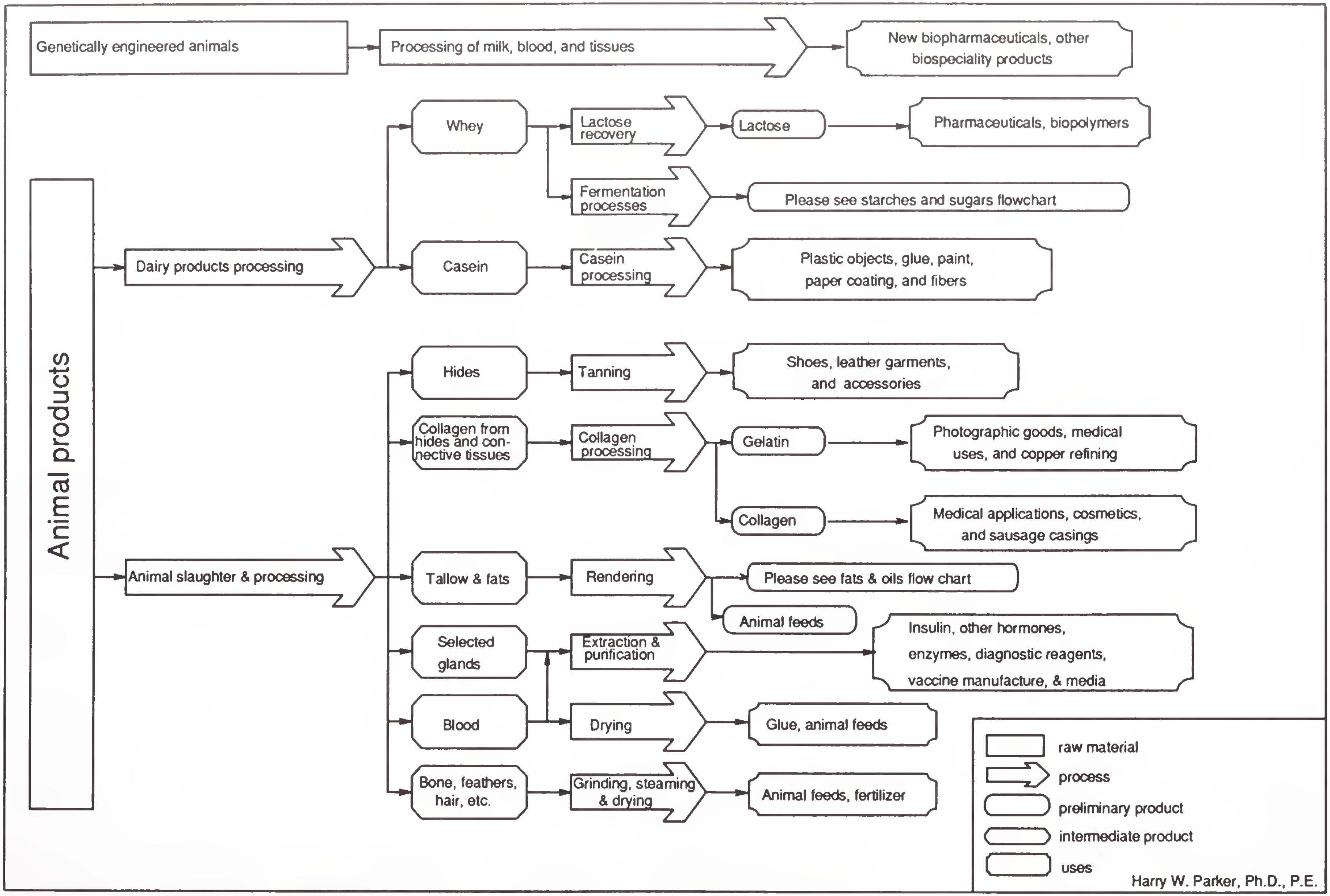
Table 12--Production and distribution of rendered products in the United States, 1990-92

Year	1990	1991	1992
	--Million pounds--		
Production			
Inedible tallow	5,723	5,718	5,775
Edible tallow	1,207	1,255	1,530
Lard	880	914	987
Meat and bone meal	5,060	5,240	5,230
Feather meal	564	617	682
Poultry byproduct meal	902	987	1091
Total	14,336	14,731	15,295
Domestic consumption			
Inedible tallow	3,285	3,078	2,888
Edible tallow	930	938	1,220
Lard	807	816	872
Total	5,022	4,832	4,980
Exports			
Inedible tallow	2,028	1,939	2,291
Edible tallow	252	285	332
Lard	87	120	136
Meat and bone meal	207	216	336
Feather meal	75	62	76
Total	2,649	2,622	3,171

Source: Render, April 1993, p. 12.

Figure 9

Processing Animal Products into Industrial and Consumer Products



Bones and bone meal are valuable animal byproducts used in a variety of products. Bone meal is used primarily in specialty fertilizers, but also as a feed ingredient in various animal rations. In 1992, over 5.2 billion pounds of meat and bone meal (MBM) were produced in the United States. Most was used domestically, with an estimated 336 million pounds being exported (table 12). Bones are also used to make: buttons, bone china, glues, adhesives, gelatin for photographic film, paper, emery cloth, sandpaper, and combs.

Inedible blood is used to make shoe polish and in leather sizing. It is also used as a feedstock for glues and animal feeds. Dried blood contains about 87 percent protein. It can also be used by calico printers in fixing certain pigment colors in cloth. Dried blood imports were valued at $619,000 in 1991/92.

Poultry Waste Recycling Is on the Rise

Most poultry processing byproducts are recycled as feed. This includes byproducts from processing plants, prematurely dead birds, and hatchery wastes. Waste products from poultry rendering plants (poultry tankage) includes feathers and the remainder of products not used for other purposes. From 1990 to 1992, the volume of poultry byproduct meal produced in the United States increased from 902 million pounds to over 1.1 billion pounds, an increase of almost 21 percent. Most of this was used in the domestic feed industry.

Feather meal is a concentrated source of protein. It is the richest common source of the amino acid cystine. The amino acids in feather meal have been shown to be 94- to 98-percent available to chicks in feeding trials. Feather meal has become a widely accepted and dependable feed ingredient. Properly processed feather meal is very uniform because it is a single-source protein. Such proteins have a relatively constant composition and amino acid profile.

Most of the protein is keratin, which in the raw or natural state is not readily digestible by animals. Modern processing methods that cook the feathers under pressure with steam partially hydrolyze the protein, breaking apart some of the chemical bonds that account for the peculiar structure of the feather fibers. The resulting feather meal is a free-flowing palatable product that is easily digested by all classes of livestock and poultry.

Feather meal and poultry byproducts have been fed to broilers, composing 7 percent of the total ration, with no adverse impacts on weight gain or mortality. Recent research suggests that byproduct feed could be increased to 12.5 percent of the diet and still support excellent broiler growth; however, bird performance during the growing period may be variable.

Feather meal production in the United States increased from 564 to 682 million pounds from 1990 to 1992, an increase of almost 21 percent. As with poultry byproducts, most feather meal is used domestically. Still, about 76 million pounds were exported in 1992.

Hatchery waste has also been identified as a valuable feed ingredient. The composition of broiler-chick hatchery waste indicated the significant amounts of protein, calcium, phosphorus, and fat. The amino acid availability from eggshell meal was found to be compatible with that from a combination of wheat middlings and meat and bone meal or soybean meal. Calcium from eggshell meal was readily utilized in feeding trials.

A substitute for camel-hair brushes is made from the delicate hairs on the inside of the ears of cattle. Hog bristles for making brushes were formerly imported from China, but are now being produced in the United States in increasing amounts.

Recycled Dairy Processing Waste Boosts Industrial Uses

Whey from dairy processing plants can be fermented and used to produce ethanol. At least seven ethanol production plants in the United States use whey as their primary feedstock material, with an average production capacity of over 1 million gallons a year.

Lactose can also be recovered from whey for use as a feedstock in making various types of pharmaceuticals. It is a white, sweet, crystalline, water-soluble compound that can be used in infant formulas, confections, other foods, bacteriological media, and as a diluent and excipient in pharmaceuticals.

Wash water solids (WWS) are small amounts of cheese that can be recovered from the cleanup waste stream. Results of a recent turkey feeding trial show that during 18 weeks, birds fed a diet with 10 percent WWS that had been processed through a twin screw extruder weighed an average of 32.2 pounds, compared with those receiving a traditional soybean protein diet weighing an average of 31.4 pounds. The cost per pound of gain was similar for the two diets. So, instead of a tipping fee for disposing of WWS, a valuable animal feed can obtained. Research on more efficient extraction of WWS and additional feeding trials are continuing.

All Casein Is Imported

Casein is the principal protein in milk, accounting for approximately 3 percent of the weight of whole milk, and 80 percent of the total protein content. Prior to World War II, all casein was used for industrial applications, such as for glues, adhesives, paper coatings, and paints. Food use increased after the war. In 1970, about half was still used for industrial products. But by the 1980's, industrial use had slipped to about 15 percent. There is some evidence that the share stabilized in the 1980's, and may have increased recently.

Casein is used as a combined dispenser and binder of pigments in leather finishes, and to furnish a glaze and a protective shield for many leather products, like shoes. It also serves as a dispensing agent in the manufacture of rubber-dipped goods, such as gloves, medical supplies, and balloons; and as a stabilizer for resin-emulsion and latex paints.

Casein has not been produced in the United States since 1968. The structure of the Federal dairy support program that favors nonfat-dried-milk production and subsidized dairy production abroad means that the entire U.S. supply is imported.

Recently, however, two small companies have begun evaluating the production of casein to make casein-based paints. In 1992, 74,600 metric tons of casein were imported, up from 65,400 tons in 1989. With value slipping from $310.8 million in 1989 to $295.6 million in 1992, prices are coming down. This makes casein more attractive for industrial applications.

Wool Grease and Collagen Used by Industry

The degreasing of sheep's wool removes an oil that amounts to about 15 percent of the weight of the wool. This oil is a source of lanolin, which is used as the basis for ointments, cosmetics, leather dressings, and fiber lubricants.

Collagen is found in hides, sinews, horn piths, pizzles, mammary glands, lips, ear tubes, knuckles, feet, and bones, as well as in the heads of cattle, calves, and sheep. The collagen in these animal parts is a source of glue. It is similar to glue in composition, but is insoluble in water at ordinary temperatures. However, in boiling water, collagen breaks down to form a water-dispersable glue or gelatin.

Collagen can also be used in medical applications, such as for burn dressings, and to treat severe acne. Once collagen has been extracted from the animal hide, it is processed into a form that permits it to be injected under the skin of acne patients. Beneath the skin, the product gradually polymerizes into an elastic, semisolid state. The mass is quickly "colonized" by blood vessels and is thus permanently incorporated into body tissues, smoothing the skin's surface. Collagen also can be used to make sausage casings.

The two types of gelatin, according to their source, are hide gelatin and bone gelatin. Gelatin is used in both edible and inedible products. It is used widely in pharmaceutical preparations and capsules for medicine, and for coating pills. Gelatin is quite important in photography, which requires a very high grade for use as a coating on the film and developing paper to obtain high-quality photos. Gelatin is also used in making audio, television, and video tapes; x-ray and movie film; computer discs; and computer tapes. [Donald Van Dyne (314) 882-4512 and Gregory Gajewski (202) 219-0085]

Forest Products

New products that conserve forest resources are on the rise. They are made from new technologies that produce paper, chemicals, and construction products, often from recycled wood wastes and underutilized forest byproducts. Using recycled wood fibers to make construction products reduces landfill needs and generally requires less energy than comparable products from metal, plastics, and concrete.

Biopulping and other advances in making paper are more efficient and generate less chemical waste. New lumber composites are reducing the demand for old-growth wood and offer improved performance and design characteristics. New uses of lignocellulosic plants also hold promise for increased energy and chemical production. These will come about through direct combustion, thermochemical conversion or saccharification, and fermentation.

Timber Markets Tighten

Traditional sources for lumber and plywood from the western United States and Canada have been reduced, reflecting shrinking inventories of old-growth forests and growing environmental concerns about maintaining ecosystems. For example, harvests from Federal forest lands dropped about 75 percent between 1988 and 1992, and are expected to remain down. The forest industry has increased production in the southern United States, but growing demand for forest products has caused rising timber prices and concern about long-term shortages of timber.

Composites account for 20 percent of the forest product industry, and are growing 10 percent per year. Output of other timber products has been fairly stable. Advances in combining wood and nonwood materials, such as plastic and metal, permit manufacturers to develop new products that have beneficial properties from both materials.

New uses for nontraditional products include producing industrial chemicals and fuel ethanol from woody cellulosic biomass. The use of wood wastes or recycled fibers to displace coal for electricity generation is also being improved.

The total harvest of timber products is about 365 million tons, of which about 300 million come from roundwood. About 200 million tons are softwoods, such as pines and firs, while the remainder are hardwoods. About 10 percent of the harvest is residuals. About half of the residuals could be converted into a variety of chemicals, ranging from fuel ethanol and methanol to organic adhesives, plastics, or synthetic rubber. Most mill residues are either being used for reconstituted products, woodpulp, or as fuel (figures 10 and 11).

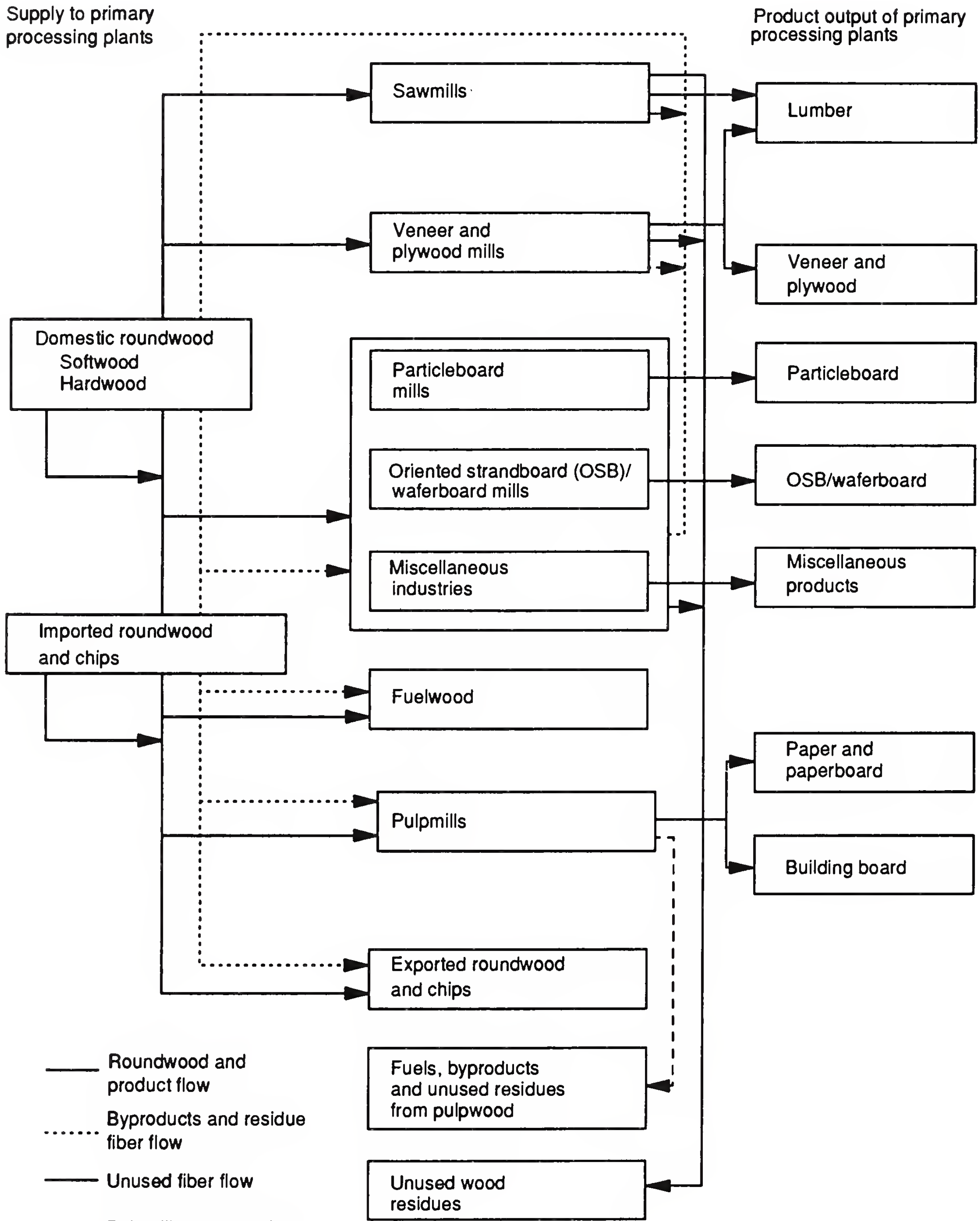
Housing Industry Takes Most Lumber and Wood Products

Lumber and other products made from solid wood account for 5 percent of U.S. Gross National Product. New home construction takes about 40 percent of timber products, while residential repairs and alterations account for 25 percent. Furniture and other household uses take another 10 percent. Pallets and other shipping materials have become a major use of lumber in recent decades, growing at 5 percent per year.

Lumber shipments were $18.3 billion in 1992, about equal to 1988 and 1989. Most wood products made in the United States today use virgin (i.e., first-cut, not recycled) timber.

Figure 10

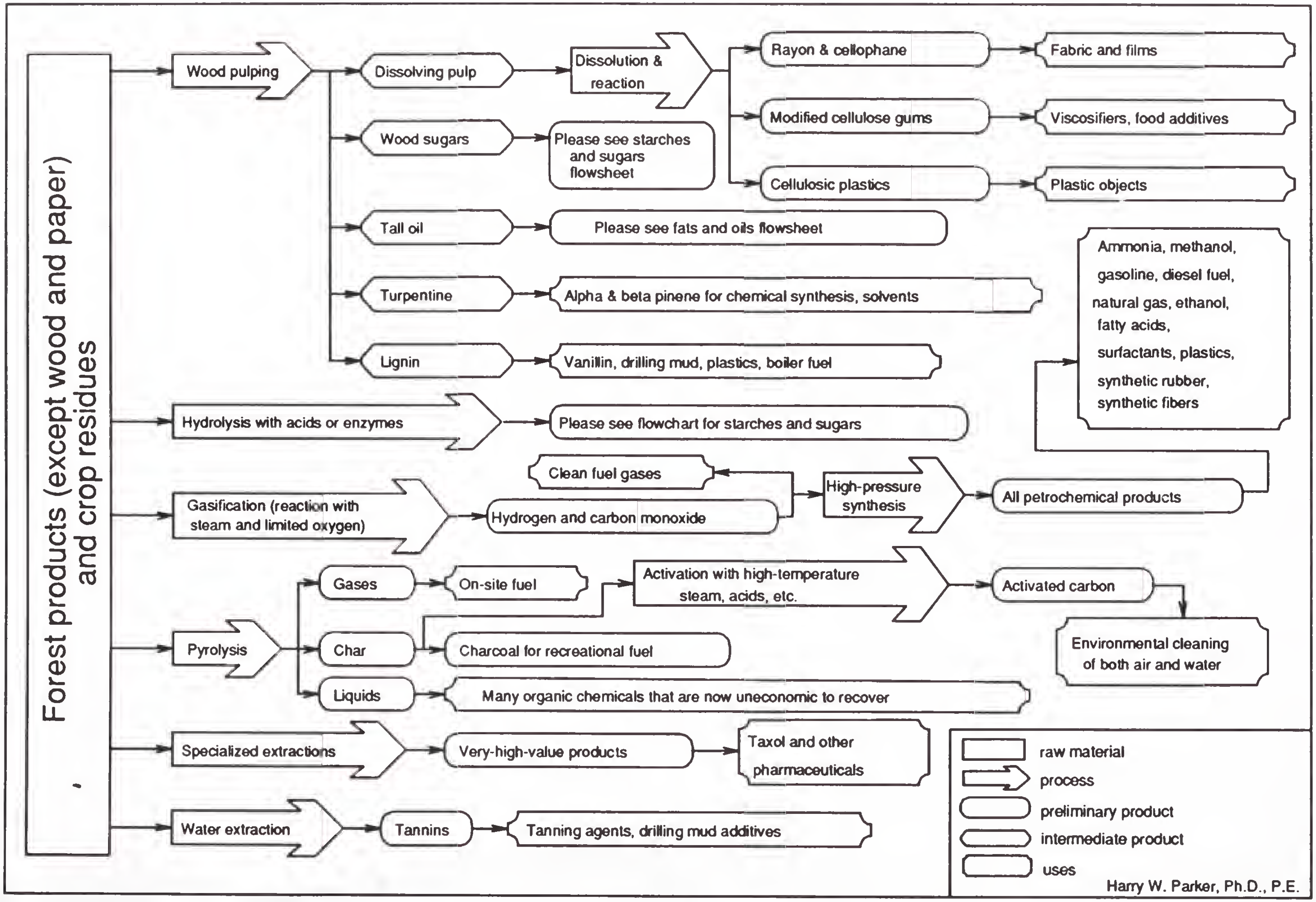
Timber Supply to and Product Output from Primary Processing Plants



Source: An Analysis of the Timber Situation in the United States, 1989-2040, USDA, Forest Service, December 1990.

Figure 11

Processing Forest Products and Crop Residues into Industrialand Consumer Products



More than half of the timber is from land owned by farmers and other individuals, more than a third is from forest-industry land, and the remainder is from public lands.

Wood-derived fuels produced 2.7 quads (quadrillion Btu's) of energy in 1986, which was 3.7 percent of the U.S total, up from 2.1 percent in 1970. Over half of the wood harvested in the early 1980's ultimately was burned for energy. Much of that was pulpmill and sawmill wastes that were used for power. Residential and commercial fuelwood use has moderated in recent years because energy prices have declined and stabilized. In some areas, use is down because of concerns about air quality.

Recently, the Department of Energy has studied the possibility of large-scale liquid fuel production from large, intensive forest plantations. With practices similar to modern agriculture, high-yield plantations of fast-growing trees could produce up to 10 tons of biomass per acre. Such plantations could provide a steady renewable source of fuel for cogeneration power plants to produce electricity and steam, or of raw materials for chemical or alcohol production. DOE's Short Rotation Woody Crops Program has been developing technologies to produce woody biomass and herbaceous energy crops at a price competitive with other alternatives.

Silvichemicals account for about $1 billion of forest product shipments. These include naval stores--rosin, turpentine, fatty acids, and pine oil. Rosin is used for sizing paper and to produce synthetic resins and adhesives. Turpentine is used as a paint solvent, and increasingly as a chemical raw material for synthetic pine oils, polyterpene resins, and adhesives.

Most silvichemicals are now derived as byproducts of the sulfate (kraft) pulping process, rather than the traditional oleoresin (gum) collection from southern pine trees. Crude tall oil production rose from 715,600 metric tons in 1982 to 901,400 in 1989, before declining to 855,700 in 1991. That drop was likely due to the recession. Crude tall oil is a major source of fatty acids (figure 5 and table 30). Other byproducts of chemical pulping processes (sulfate and sulfite) derived from spent pulping liquors include various lignin derivatives, ethanol, acetic acid, and vanillin.

Laboratory work has shown that petroleum-derived phenolics in adhesives can be replaced with phenol substitutes from wood. DOE and private firms are now developing pilot-scale projects to demonstrate commercial feasibility.

Some scientists say that unique chemicals that are not now commercially available can be derived from wood. For example, trees and other forest products contain biopharmaceuticals like taxol that are waiting to be discovered and isolated (see the Specialty Plant Products Section).

Biotechnology may also increase the production of chemicals and biopharmaceuticals from wood and other biomass. For example, wood-derived sugars fermented by yeast produce roughage for animal feeds and some human foods, wood molasses, and single-cell proteins for human and animal nutrition. Biotechnology also promises to lower the cost of producing ethanol from woody crops.

Biotechnology also has provided methods of bioremediation in waste disposal. Bioremediation is the use of microorganisms, such as bacteria and fungi, to degrade hazardous wastes to harmless products. Recently, lignin-degrading fungi have been shown to be helpful in breaking down harmful chemicals, such as the wood preservatives pentachlorophenol and creosote.

Modest Growth Ahead for the Pulp and Paper Industry

The U.S. pulp and paper industry has grown about 2.5 percent per year in the last decade and is likely to continue to grow at about that rate for the next decade, in tandem with world production. Competition in world markets is likely to increase as pulp output rises in Brazil and other Latin American countries and, in the future, from Siberia. For the next several years, increases in domestic paper production are likely to come primarily from recycling. After 2000, increases in mechanical pulping and perhaps biopulping are expected to help meet the growth in paper demand.

Woodpulp is the primary raw material for nearly all paper products. Typically, paper and paperboard products are grouped according to use, such as newsprint, printing and writing papers, tissues, linerboard in corrugated containers, and kraft papers. About 80 percent of paper is made through chemical pulping, while the remainder is made through mechanical and semi-chemical pulping. Recent technological advances have increased the range of species used in pulping to include a larger share of hardwoods.

Pulp produced by the kraft process is the major papermaking raw material in the United States. Residual brown-colored lignins that remain after the pulping process must be removed by a bleaching process, to increase the pulp's brightness, prior to papermaking. This process uses chlorine chemicals that have unfavorable environmental effects.

Several methods are under investigation to lower environmental impacts and pulping costs. A 1983 report by the Office of Technology Assessment mentions enzyme treatments as a technologically feasible alternative. DOE-funded work at the National Renewable Energy Laboratory (Golden, CO) is developing pulping technologies, such as the "organosolv" clean fractionation processes and steam explosion technologies for paper, biofuels, and chemical feedstocks. Steam explosion technologies are also showing promise as pretreatments for lignocellulosics. These and other technologies are receiving support from USDA and DOE.

Another new technology is biopulping, the pretreatment of wood chips with white-rot fungi. Examples of its benefits include reduced chemical use, increased strength properties, decreased energy and waste treatment costs, and lower capital investment per unit increase in production capacity. Biopulping has been successfully demonstrated using aspen and lob-

lolly pine. In the future, biopulping may be adapted to more species by developing designer biopulping organisms using genetic engineering techniques.

Since the late 1980's, concerns about solid waste disposal and the environment have increased the amount of wastepaper recovered for recycling. The amount of wastepaper recovered has risen from 26 percent to 38 percent in the last 10 years and is expected to continue to rise to 45 percent or more. The paper industry has instituted a program of recycling to increase the utilization of waste paper. Most of the new mills added in 1992 use recycled fibers as a major input for papermaking.

Wastepaper supplies are centered in metropolitan areas, which may be far from existing mills in forest areas. As a result, prices for wastepaper, like old newsprint, have been negative in many cities in the Northeast. To foster markets for recycled materials, many local governments have passed mandatory recycled-paper-content rules for many types of paper. In addition, voluntary use of recycled products by large corporations, such as McDonalds, and mandated procurement policies by Federal and State government agencies have helped expand the use of recycled products. Large quantities of wastepaper also are exported.

Wood Composites Show Rapid Growth

Over 70 percent of all finished wood-based products used today contain some type of adhesive, and that figure is expected to grow rapidly as new products and processes are developed. Composite products include laminated beams, plywood, laminated veneer, various fiberboards, waferboard/oriented strandboard (OSB) panels, particleboards, overlays, composite lumber substitutes, and composite matrix materials that combine wood and nonwood materials.

Low-density fiberboards are used for insulation, sound deadening, and carpet backing. Medium-density fiberboards are often used in furniture. High-density fiberboards find their way into wood I-beam webs, furniture, and paneling substrates. Wood-based composites offer optimized performance, minimized weight and volume, cost effectiveness, fatigue and chemical resistance, and controlled biodegradability.

The large potential for technological change in forest products comes largely from advances in composite technology. In the last 50 years, solid-sawn lumber and timber construction have given way to this composite evolution. The introduction of waterproof petroleum-based adhesives gave impetus to the development of the plywood industry. Plywood became a superior replacement for 1-inch lumber in sheathing of housing frames.

Structural lumber substitutes are a rapidly growing segment of the wood products market today. This includes laminated-veneer lumber and parallel-strand lumber. These products have enhanced properties that exceed conventional sawn-timber products. Laminated wood is 3 times as strong as conventional timber, and could challenge steel and concrete as a building material.

For example, Trus Joist MacMillan (Boise, ID) is making a composite that reduces the need for old-growth lumber. They manufacture wood I-joists made from smaller-diameter, second- and third-growth timber. The company uses resins to laminate smaller pieces of trees into structural beams comparable to those milled from older, larger trees.

The industry has produced mainly price-sensitive commodity composites. Insulating board, hardboard, and structural panels--which include plywood, OSB, and waferboard-type products--have shown steady growth but have lost some market share to competing products made from steel, aluminum, vinyl, and plastic expanded foams. Similarly, particleboard and hardwood plywood have lost some market share to competitors in recent years. Without cost-saving technical advances, opportunity for growth will be limited in the next 20 to 30 years.

New Uses of Composites Rely More on Recycled Products

High-speed processing is making composite-wood products more competitive by lowering cost and improving quality. Now, for example, thermoplastic resins are thoroughly mixed with finely ground wood particles or flour using extrusion or injection molding technology.

In another new composite, a high percentage of natural fibers are blended with synthetic thermoplastic or thermosetting fibers to form a nonwoven mat that can be made into panel products or deep-drawn molded configurations. Because of the increased processing flexibility inherent in the new technologies, they can be used to make packaging, manufactured products, and building materials.

Great potential exists for developing products for housing made from recycled wood waste and wastepaper, which will also reduce demand for landfill space. Wastepaper is the single largest component of municipal solid waste (MSW). At approximately 73 million tons per year, wastepaper accounts for 38 percent of all landfilled material. Excluding paper, about 8 percent of landfilled material is wood waste. According to EPA, by the year 2000, about 10 million tons of wood waste will enter the municipal solid waste stream each year.

The types of wood waste that have potential uses in housing products include full-sized used lumber salvaged from razed buildings, wood broken up during building demolition, old wood pallets, scrap wood from new construction sites, preservative-treated wood waste from treating facilities and building construction, old wood utility poles and railroad ties, wastepaper, and wood fibers in paper-mill sludge. Most of these raw materials will require chipping, grinding, or fiberizing to reduce the nonuniform waste into a uniform material for processing.

Several technologies with the greatest potential for success include dry-formed reconstituted wood products from fibers, flakes, chips, or particles; wood/plastic combinations;

Recycled Fiber Composites Will Soon Hit the Market

Several companies are moving ahead with recycled wood products. Wood Recycling, Inc. (Peabody, MA) uses a patented process to convert urban wood waste into wood fiber with applications in composite boards and pulp and paper. The company's primary facility can take in, separate, and sort as much as 1,000 tons per day of demolition and construction waste, and convert the wood fraction into wood chips. Their secondary facility converts the recycled wood chips into wood fiber, and then formulates and packages it for sale.

Gridcore Systems International Corp. (Carlsbad, CA) uses recycled wood, paper, cardboard, or any other fiber source (including kenaf) to make Gridcore panels. The panels are molded fibers cast into sheets with one smooth surface and one waffle-textured surface. According to the company, the material forms a lightweight, sturdy panel aimed at the housing and construction industries. The company's first production line, based on the Spaceboard technology licensed from USDA's Forest Products Laboratory, is scheduled to start in mid-summer.

Phenix Composites, Inc. (Mankato, MN) makes Nustone, a composite building material, out of waste paper and soybean meal. According to the company, the material looks like granite but has the construction properties of wood. It can be manufactured into panels, blocks, or veneers and colored to simulate many granite hues. Phenix has samples of Nustone and plans to open a medium-size facility by the end of the summer.

wood/cement combinations; wet-formed wood products from fibers; reuse of old lumber from razed buildings; and remanufacture of lumber from short pieces of construction waste.

One promising process involves crushing the wood into splinters. This offers advantages over other wood-reduction techniques since no cutting is required, eliminating the need to sharpen blades that may be damaged by contaminates. Because splinters have high length-to-cross-section ratios, splinters make strong composites. Dry hardwoods splinter exceptionally well, so this technology seems like a natural outlet for used hardwood pallets. This splintering process has shown potential in Australia where a structural-wood product called Scrimler has been developed.

Another potential technology, making wood-flake-based products from recycled wood, may be more difficult. Wood flakes are manufactured by cutting or slicing flakes from solid wood pieces. The raw material should have a high moisture content and must be properly pre-sized to produce a consistent product. So, flake technology will probably be most useful where the waste stream is very controlled. Flakes are commonly used in sheathing products, such as OSB, which in turn is used as roof, floor, and wall sheathing.

An existing, though not widely used, building product combines recycled wood with an inorganic binder such as portland cement. Considering that over 50 percent of all the southern pine lumber cut today is treated with some sort of preservative, it is conceivable that an increase in this type of material in the waste stream will occur. A cement-bonded product is attractive because it has a long life expectancy.

Paper recycling faces significant barriers, including costs for collection, sorting, transportation, and contaminant removal (ink, clay, adhesives, plastics, etc.). In addition, there is a limit to the number of times paper can be recycled and still retain its original properties. However, these fibers can be converted into housing construction materials.

Research is underway to produce housing components from recycled wastepaper fiber. A pulp-molding process makes a structural housing component called Spaceboard (see box). A pulp-extrusion process has the potential to produce casing and trim products. A third type of wet-formed, fiber-based process involves shaping structural components through the winding of papersheet stock. This process can make round, rectangular, and other desired cross-sectional shapes.

Developing products that can be easily formed or molded may have special application in wind-resistant design, as well as improved energy-efficient design. For example, structures with curved or rounded edges or shapes are more aerodynamic, more energy efficient, and require less material to enclose a given living area than square or rectangular shapes. Moldable structural composites from recycled waste might be used to fabricate stress-skin panel corners to replace the conventional three-stud corner. This would reduce heat loss, improve shear performance, and reduce wind pressures due to turbulence around the building corner in heavy winds. [Thomas Marcin (608) 231-9366]

Specialty Plant Products

Developing alternative sources of the drug taxol is limiting the long-term opportunities to commercially farm the Pacific yew tree, but there may be some opportunities for growing other species of yews. Some experts predict that in 3 years, taxol will be made from laboratory semisynthesis, cell tissue culture, and fungal metabolites. This will take the pressure off the rare Pacific yew.

Today, over 90 percent of natural rubber comes from the hevea tree in Southeast Asia. Guayule, a desert shrub native to the southwestern United States, is also a source of natural rubber, but is now not competitive with hevea for traditional rubber markets. A DOD-USDA project has about doubled guayule yields, and work continues on making this crop more economical. But a new niche market may open up for medical gloves, condoms, other consumer items, and toys

500,000 people in the United States are allergic to hevea-based natural latex products. And the latex from guayule has been shown to be hypoallergenic for people allergic to hevea products.

Pacific Yew Plantations Have Been Planted

Taxol, a compound found in the bark of the Pacific yew tree, was cleared by the Food and Drug Administration in record time for treating ovarian cancer patients who have failed to respond to other treatments. The drug is also being tested for fighting breast, colon, lung, skin, kidney, and prostate cancer.

Even though there are a number of potential sources of taxol, FDA has approved only taxol derived from the bark of the Pacific yew tree for human use. Approximately half of the bark harvested comes from the private sector, with Weyerhauser being the major supplier. According to the National Cancer Institute (NCI), several nurseries and forestry companies have already planted up to half a million trees, and expect to begin harvesting in 1994.

At present, the bark is stripped off of the Pacific yew tree, which is native to the Northwest, and processed into the drug. Bark from three to six mature yews is required to make enough taxol to treat one cancer patient, and the trees take 80 to 100 years to reach maturity. Several environmental groups are trying to get the Pacific yew on the protected species list. The discovery of taxol has, according to USDA's Forest Service, increased the yew harvest to 38,000 trees per year (825,000 pounds of bark). Prior to the discovery of taxol's effectiveness, the Pacific yew was of no commercial interest.

Researchers have found that taxol can be processed from the needles, twigs, and branches of several yew species thus eliminating the need to kill any trees in order to get the drug. Bristol-Myers Squibb (BMS), the sole supplier of taxol to NCI, predicts that no Pacific yews in the wild will be required for taxol production within 3 years.

How Far Along Are the Alternative Sources?

Currently, most production research is focusing on the semisynthesis of taxol. Chemists begin with precursors from the twigs and needles of several common species of yews grown in the United States, including the European yew and the Asian yew, and various ornamental yews. The precursors can also be produced using plant cell tissue culture technology. The existence of these sources has ended supply problems and has put the issue of harvesting wild Pacific yews to rest.

Now, BMS is buying precursors derived from yews harvested in India from an Italian natural products company. BMS predicts that semisynthetic commercial production will provide as much as half of the taxol used for patient treatment in 1994. FDA approval for semisynthetic taxol is expected within the year.

Taxotere, a taxol-like, semisynthetic compound derived from yew needles and twigs, may be even more promising than taxol itself. The drug is produced by RhonePoulenc Rorer. The compound appears to have similar, if not better, results than taxol against all forms of cancer and works in much the same way as its natural counterpart. Unlike taxol, taxotere is water soluble and is thus much easier to administer, requiring only a few hours in the hospital. Now, an overnight stay is required for a taxol treatment.

The newest method of producing taxol is also one of the most promising. Researchers at Montana State University have discovered a fungus in the folds of a single yew tree's bark in Glacier National Park that produces taxol on its own. Field experts have been unable to find samples of the fungus (*Taxomyces andreanae*) on other trees. Many pharmaceuticals, including all antibiotics, are made with fungal metabolites. This method of production has the potential to be the cheapest source of taxol in about 5 years.

Cell tissue culture is another possibility. Now, no pharmaceuticals have been commercially produced in the United States using this new technology, but ESCAgenetics and Phyton Catalytics see potential for this method of production for taxol. Both firms, along with NCI and BMS, foresee large-scale commercial production of taxol (100 kilograms per year or more) from tissue culture technology within 1 to 2 years. The process involves growing yew tree cells, cultured in fermentation vats, to produce taxol and taxol-like compounds.

Complete synthesis of taxol is very difficult. Stanford researchers say they are very close to synthesizing taxol from pinene, a primary component of turpentine. Even though pinene contains half of the molecular structure of taxol, the synthetic form will probably never be commercially produced due to the high cost of the 15- to 25-step chemical process.

A New Niche For Guayule?

According to Scientist Katrina Cornish of USDA's Agricultural Research Service, people who suffer from prickly rashes and other allergic reactions to latex gloves may be helped by using latex processed from guayule. Guayule's natural rubber appears to be free of the allergy-causing proteins found in latex made from the hevea rubber tree. Allergen-free rubber extracted from guayule stems and bark could be used to make gloves for medical and lab professionals, and other latex products, such as toys, condoms, and elastic used in clothing.

In recent years, the demand for latex gloves and condoms has increased dramatically. Sales of prophylactics rose from 61,855,800 dozen in 1982 to 151,231,000 dozen in 1987. The value of prophylactic sales rose from $54.7 million in 1982 to $103.3 million in 1987, to an estimated $117.7 million in 1991. Surgical rubber glove sales rose from 28,666,300 dozen pairs valued at $156.7 million in 1982 to 97,398,900 dozen pairs at $234.5 million in 1987, the latest available data. A private survey of U.S. manufacturers shows that production of medical latex gloves rose by 50 percent

between 1987 and 1991. This increased demand opens up the possibility for guayule to fill a niche market for those who are allergic to hevea rubber.

Moving to other parts of the plant, guayule's resin shows the most promise as a high-value coproduct. For every pound of rubber produced, a pound or more of resin is obtained. Guayule resin can be used in termite control for wood, and as a plasticizer/extender for polyvinyl chloride and more expensive epoxies. Another major coproduct, low-molecular-weight rubber, has potential value in rubber cements, adhesives, and low-cost elastomers. Coatings made from guayule coproducts protect against zebra mussels and barnacles, and appear more biodegradable than competing petroleum products. Guayule's bagasse can be shaped into fireplace logs and pressed boards (figure 12). Developing new uses for coproducts will be critical to guayule's commercial success.

Guayule Still a Long Way From Traditional Markets

Natural rubber is a critical material used in tires, medical supplies, resilient mounts, and acoustical applications. Nearly one-third of all rubber produced in the world is natural rubber. The United States imports all of its natural rubber, 92 percent of which comes from Southeast Asia. Natural rubber, either from hevea or guayule, has several distinct properties that give it an edge over synthetics. The properties include higher resiliency, elasticity, and more resistance to heat build-up.

Annual U.S. consumption of natural rubber is about 896,000 short tons and costs $1 billion. The Department of Defense estimates that increased military uses of natural rubber in a conventional war situation would be equal to about 20 percent of current civilian consumption. Synthetic rubber was developed during World War II in response to a cutoff of natural rubber supplies. After the war, synthetics claimed a progressively larger fraction of the world rubber market.

Because synthetic rubber is made from petroleum, a shortage of oil would lead to higher synthetic rubber prices which in turn would lead to higher demand for natural rubber. Recent events in Kuwait and Iraq show that there continues to be a potential for disruptions to the supply of petroleum.

Guayule provided 10 percent of the world's natural rubber in 1910. However, after World War II, cultivation was abandoned. The U.S. consensus in 1946 was that there was little need for another rubber source, because people believed that synthetics could meet all needs.

DOD-USDA Effort Advancing Commerical Potential

Natural rubber's material advantages, combined with national security considerations in the 1970's, sparked renewed interest in a domestic source of natural rubber. The development of guayule in the United States could reduce dependence on foreign supplies of natural rubber and provide a new agricultural industry to the Southwest.

In 1986, DOD and USDA signed a 27-month agreement to develop guayule that was extended and is still underway. DOD provided $11 million to maintain and harvest 275 acres of guayule shrubs, build a prototype processing plant, and process the shrub into more than 50 tons of natural rubber. Also participating in the project were the Firestone Tire and Rubber Company, Dravo Engineering Companies, Inc., the Gila River Indian Community, and four southwestern land-grant universities. The purposes of the project are to:

- Determine if natural rubber can be economically produced in this country, and
- Determine if natural rubber from guayule can be used in place of imported natural rubber.

Bridgestone/Firestone has manufactured light truck tires that will undergo vehicle testing at the Yuma Proving Grounds (Yuma, AZ) under the direction of the U.S. Army Tank Automotive Research and Development Center (Warren, MI). Naval F/A-18 aircraft tires will be manufactured by Goodyear and tested at the Naval Air Warfare Center (Patuxent River, MD).

The goal is to have the capacity to produce 25 percent of the United States' natural rubber consumption. On an annual basis, this will amount to 190,000 tons of rubber worth about $210 million. Processing to produce this much rubber would require about 1 million acres of guayule under cultivation, assuming current yields (see figure 13 for potential growing areas). About 5 to 20 percent of the shrub's dry weight is high-molecular-weight rubber. Low-molecular-weight rubber, guayule resin, a water-soluble component, and bagasse make up the remainder of the fractions.

Prior to recent advances, USDA selections of guayule strains produced average rubber yields of about 400 pounds per acre per year. For commercial feasibility at current prices, rubber yields need to be increased to at least 1,200 pounds per acre per year. One goal of the DOD-USDA program is to meet this by 1996.

Recently, several high-yield strains were developed through genetic selection. Cal-6 and Cal-7, two strains developed by the University of California at Davis, produce 810 and 609 pounds per acre per year, although yields vary according to location.

Presently, guayule cannot compete with hevea on a price-per-pound basis in traditional markets. In order for guayule to show a profit, its market price would have to be $1.45 per pound, or 3 times greater than the present market price for hevea (45 cents per pound). Assuming increased yields (from 400 to 800 pounds per acre per year) and decreased costs due to improved technology (particularly direct seeding), guayule could show a profit above 68 cents per pound by 1996. Moreover, if Southeast Asian plantations are not totally replaced as they age, hevea prices could rise beyond 2000. However, rubber from guayule shows economic promise for the new niche market of hypoallergenic medical gloves, condoms, and other consumer items. [David Pace, William Moore, and Gregory Gajewski (202) 219-0085]

Figure 12

Processing Natural Rubber into Industrial and Consumer Products

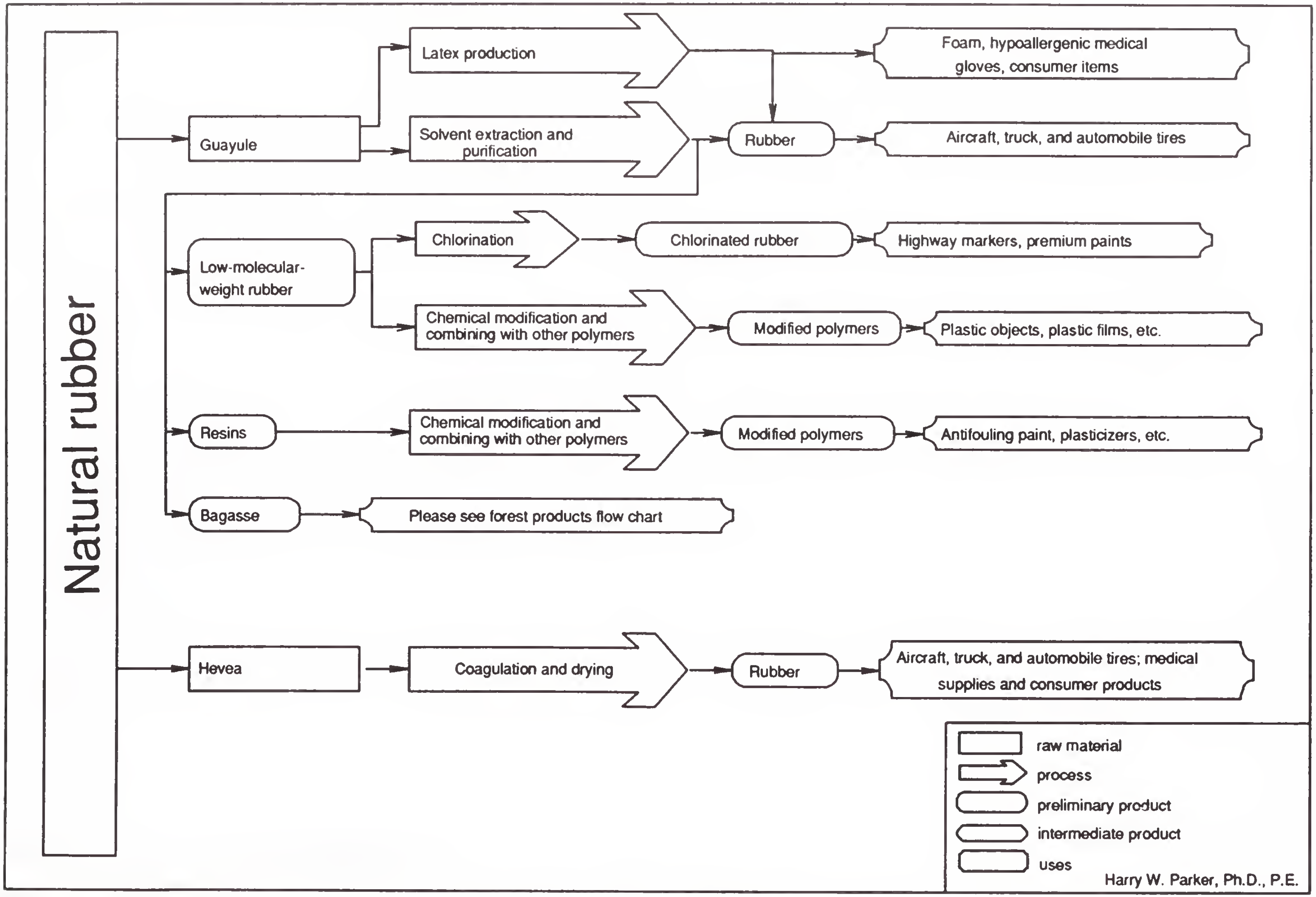
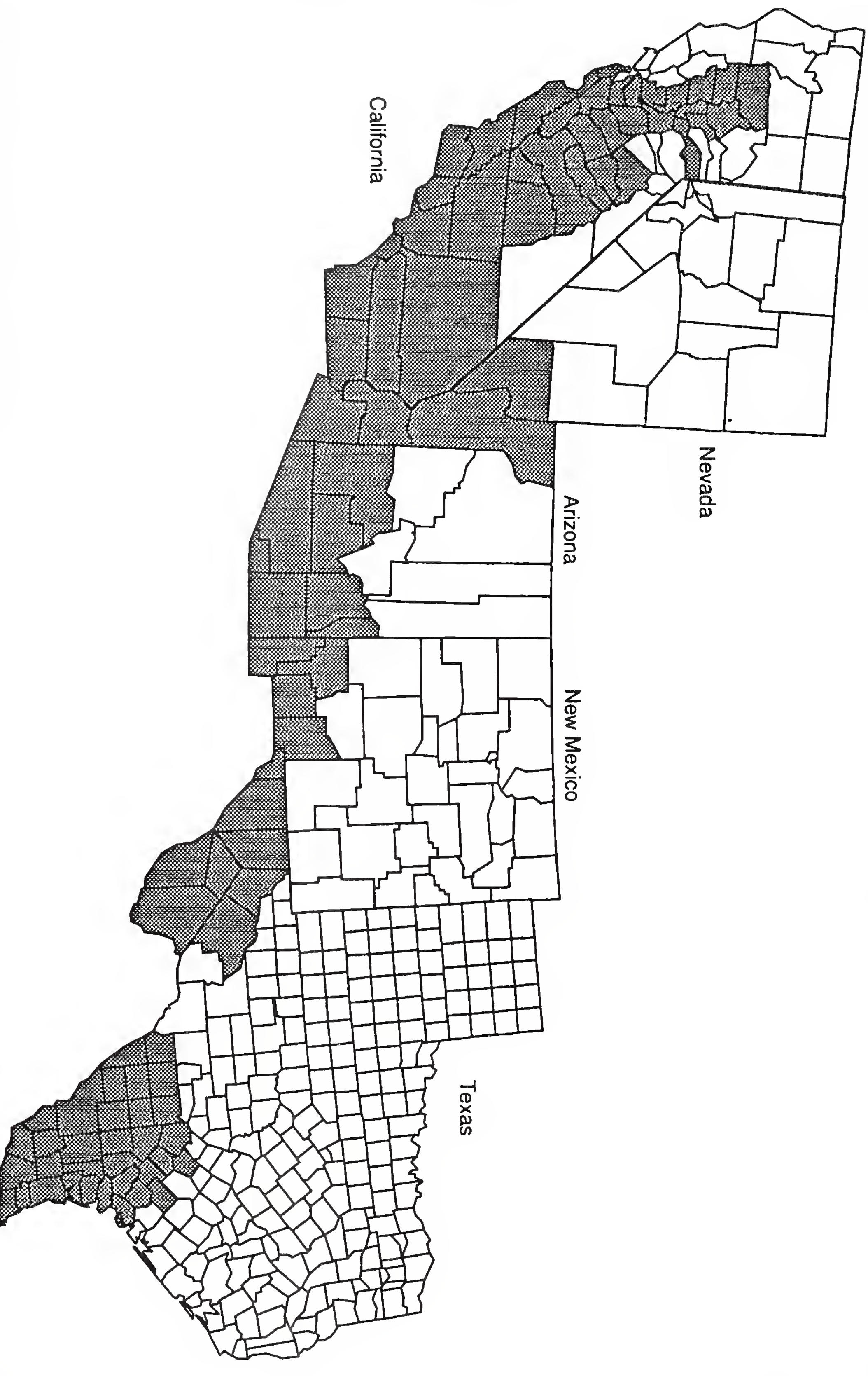


Figure 13

Potential Guayule Growing Regions



Source: Office of Arid Lands Studies, University of Arizona.

The Effects of Expanding Biodegradable Polymer Production on the Farm Sector

by

E. Douglas Beach and J. Michael Price

Abstract: *This article develops two sets of estimates of the probable growth of biodegradable polymer output to the year 2000. These estimates are then used to simulate possible impacts on the farm sector. The results suggest that net farm income will increase slightly and total government deficiency payments will decrease slightly. However, farm output will be largely unaffected.*

While increased production of corn-starch based biopolymers may represent a valuable new niche market for corn and other starch crops, such uses by themselves probably will not cause major increases in the market prices of agricultural commodities. Agriculturally based biopolymers will need to be combined with other new uses--such as for ethanol and as a feedstock for basic industrial chemicals--to help support market prices over the long term. The results here do suggest that increased support of biodegradable polymer research, development, and commercialization would decrease government outlays and increase net farm income.

Keywords: New uses, biodegradable polymers, government commodity programs.

The overall economic impact of biodegradable polymer production needs to be evaluated on an integrated scale. Impacts on farmers and farm subsidies, waste and litter management, national employment, plastic consumers, and investment should be considered. Many of these are beyond the scope of this article. However, the article does examine the environmental consequences of increased biodegradable polymer use, and develops estimates of the effects of increased biopolymer production on farmers and farm subsidies.

Estimates vary widely on the potential impacts of starch-based biopolymer production on farmers. For example, the National Corn Growers Association estimates that the use of corn to produce biodegradable polymers could require between 150 million and 300 million bushels of corn per year. According to earlier USDA estimates, this would increase the price of corn by 6 to 18 cents a bushel and decrease farm-program costs by $300 million to $900 million. However, others have estimated that corn-based biopolymer production could actually increase farm program costs [3]. Most others found a small, yet significant decrease in farm subsidies as a result of starch-based biopolymer production [7, 9].

What is Recycling and How Do Biodegradable Polymers Fit In?

Mounting environmental concerns have focused attention on designing materials from "cradle to grave." This requires that recyclability and/or degradability features be incorporated into all materials, while still retaining performance characteristics. Two distinct types of recycling are called for:

- *Materials recycling* requires processing and remanufacture, and is what we typically think of as recycling. However, there are technical limits to how many times materials can be recycled and still exhibit the desired physical properties; and
- *Waste Recycling* includes composting, and is the conversion of solid waste into useful products. This is appropriate when materials recycling is not practical or feasible.

According to many groups and the Environmental Protection Agency (EPA), composting is a means of recycling. It is efficient, cost-effective, and environmentally responsible. Now, 23 States have laws requiring that landscape and yard wastes be composted by 1995.

Biodegradable polymers, along with other organic materials that are to be disposed of in the environment, should be designed to become an integral part of the carbon cycle. Use of biodegradable polymers in place of petroleum-based plastics slows the introduction of fossil-fuel-derived carbon dioxide into the atmosphere. That is because incineration or biological digestion of renewable biomass simply recycles carbon dioxide--leaving it at current levels. Many believe that integrated waste management practices--which include recy-cling, source reduction of packaging materials, off-landfill composting of biodegradable wastes, barring of toxic colorants, and incineration--may bring waste disposal under control [5].

What Does Degradable Mean and What Are Biodegradable Polymers?

The American Society for Testing and Materials is finalizing the technical definition of a degradable plastic. Now, there are basically two types of degradable polymers that have achieved some market success: photodegradables and biodegradables.

Photodegradable plastic resins are made by introducing a sensitizing group which absorbs radiation, generally a vinyl ketone, into the structure of the plastic. The vinyl ketone monomer is stable in photochemically incandescent light but degrades in the natural sunlight of the outdoor environment.

Examples in the marketplace include Ecolyte plastic resins that are made by copolymerizing ketone-containing comonomers with ethylene, styrene, and other commercial plastics. The use of Ecolyte in food packaging is promising because the ketone monomers are nontoxic and they remain a permanent part of the polymer chain. But, during degradation, these types of polymers leave small fragments of petroleum-based plastics which must be disposed of in a landfill or incinerated.

In comparison, biodegradable polymers degrade primarily through the action of microorganisms such as bacteria, fungi, algae, and/or yeasts. Two key steps occur in the biodegradation process:

- Depolymerization or chain cleavage--occurs outside the microorganism due to the size of the polymer chain and the insoluble nature of many of the polymers; and

- Mineralization--occurs once the fragments are sufficiently small, so they can be transported into the cell to be mineralized. At this stage, the cell usually derives metabolic energy from the mineralization process leaving behind carbon dioxide, methane, nitrogen, water, salts, minerals, and biomass.

Therefore, biodegradation relies on microbes and their enzymes to convert organic matter to water, carbon dioxide, cellular material, and mineral salts.

For waste recycling, even small amounts of nonbiodegradable synthetic substances in the starting substrate are unacceptable. These materials should not be used in soil amendments because continuous application of any material that includes an inert substance, like petroleum-based plastics, would slowly build up, and decrease soil fertility and productivity. Because several biodegradable polymers are 100-percent degradable, they are being scrutinized by the Department of Defense (DOD) so that its packaging can be properly disposed of at sea.

Composting Is Needed For 100-Percent Degradable Polymers

No material, including 100-percent degradable polymers, will appreciably degrade in modern landfills. As a result, replacing petroleum-based plastics with biodegradable polymers will probably not reduce perceptibly the volume of trash in the municipal solid waste stream. So, from an environmental standpoint, the future of biodegradable polymers relies on building a composting infrastructure to transform these wastes into carbon-rich soil additives. Composting systems are designed to accelerate the degradation of organic materials through the actions of microbial organisms in a moist, warm, aerobic environment.

In the United States, composting has a large potential for achieving waste reduction goals. Industry analysts estimate that up to 40 percent of the municipal solid wastestream can be composted. Compost-amended soil can increase organic carbon, water, and nutrient retention; reduce chemical inputs; and suppress plant diseases. Professor Hoitink, at Ohio State University, has patented a composted material which suppresses four deadly microorganisms found in nurseries. Growers who had routinely lost 25 to 75 percent of their crop now lose only 1 percent, without applying a single fungicide.

A recent study by EPA addressed the economics of leaf composting in eight areas across the United States. The programs studied showed that composting costs (excluding revenues) ranged from $11 to $102 per ton and avoided disposal costs of $5 to $137 per ton. In several cases, revenues of up to $25 per ton were generated through sale of the finished product. In other cases, costs were avoided by using the finished compost for landfill cover or private use [13]. As landfill space becomes more costly, composting makes more environmental and economic sense.

Nevertheless, there are some problems with composting. In a 1992 telephone survey by the Roper Organization, more than two-thirds of the 201 solid waste experts surveyed mentioned the following as significant problems jeopardizing the future of composting: insufficient standards for compost quality, cost of separate collection of organic materials, uncertainty of future regulation, difficulty of separation in plants, lack of capital to build facilities, odor, and lack of markets for composted products. For the top 10 disadvantages, 8 in 10 of the people surveyed were at least somewhat optimistic that solutions would be found.

How Are Biodegradable Polymers Used Now?

The main use of degradable plastic has been for items where disintegration after use is a direct benefit. Examples include: agricultural mulch films, planting containers and protectors, hay twine, surgical stitching, medicine capsules, and composting bags [4, 6]. Agricultural pesticide firms are also examining the use of starch-based polymers to encapsulate products. Encapsulated pesticides offer several advantages over traditional pesticides:

- Reduced runoff and groundwater contamination,

- Greater safety in handling,

- Extended activity,

- Reduced volatility losses,

- Reduced degradative losses, and

- Reduced application rates.

Additionally, encapsulation shows promise for significantly increasing the environmental stability and pest-control efficiency of entomopathogens such as *Bacillus thuringiensis* (Bt) [1].

As biodegradable polymers expand into new markets, there are several challenges that must be met. The primary one is to design polymers that work when needed, but self-destruct after use. Moreover, performance must meet public expectations and provide value relative to paper and plastic substitutes.

Another challenge is to determine the environmental impact of biopolymer degradation, both in its intended disposal method and in litter. The promise of 100-percent biodegradability does not lessen the need for increased environmental fate studies on all forms of polymers. The EPA feels that there are too many unanswered questions regarding the impact of biodegradable polymers on different environments and is opposing recent legislation which promotes increased use of these products [10]. More specifically, questions must be answered on:

- Whether a polymer is degradable and, if so, under what conditions and in what time frame,
- The potential environmental impact of increased degradation products and additives from a degrading polymer,
- The potential impact of small pieces of degrading polymers in terrestrial and aquatic ecosystems, and
- The potential impact of degradable polymers on recycling programs.

Provided that manufacturers continue to use biodegradable polymers and natural biodegradable additives, the answers should favor many of these products.

Promising Technologies Ahead

Polylactic acid polymers look very promising. They are generally derived by fermenting carbohydrate crops, such as corn, wheat, barley, cassava, and sugar cane. These polymers can also be made from cheese whey and potato wastes. Commodity giants like Archer Daniels Midland and Cargill produce lactic acid as a byproduct of corn wet milling.

Battelle Memorial Institute's Senior Research Chemist, Dr. Richard Sinclair, describes polylactic acid polymers as "nice well behaved thermoplastics which can, in its various compositions, mimic all the physical properties of conventional packaging plastics" [2]. Moreover, polylactic acid polymers degrade back to lactic acid--a natural, harmless product. While properties of these polymers are excellent, full realization of its potential will depend on improved preparation and recovery of the basic fermentation chemicals. To improve the economics, better technology is required to readily recover lactic acid from the fermentation broth.

To date, the relatively high price of polylactic acid polymers, compared to petroleum-based plastics, has restricted their commercial application. Polylactic acid polymers have achieved some success in the high-priced medical field. Producers of polylactic acid polymers include Cargill, and joint ventures between DuPont and ConAgra, plus Battelle Memorial Institute and Argonne National Laboratories.

A second technology which has received a great deal of attention is the poly-hydroxybutyrate/valerate (PHBV) copolymers developed by International Chemicals, Inc. (ICI). ICI has developed a process where bacteria act on a controlled feedstock of organic acid and sugar to produce PHBV, which can be harvested. The production technology is similar to the bacterial fermentation of corn to ethanol. PHBV completely biodegrades in a microbially active environment, such as a composting facility or a sewage plant [11].

Like polylactic acid polymers, the relatively high cost of PHBV, compared to petroleum-based resins, has prevented it from significantly penetrating the plastics market. Companies that have product agreements with ICI generally pay $8 to $10 per pound of resin. ICI officials expect the price to drop to $4 per pound by the mid-1990's. Market successes include injection-molded bottles used by Wella for its Sanara brand shampoo, and by Brocato International for a new line of hair care products called Evanesce.

The final technology is receiving the most attention at USDA. Starch-based biopolymers begin with starch that is relatively inexpensive (cornstarch is approximately 7 cents per pound), can be thermoprocessed using conventional plastic processing equipment, and is available as a surplus raw material from agricultural production. However, polymers with improved water resistance require specialty starches, which are more expensive than other starches. Another advantage of starch-based polymers is that they are biodegradable on land and at sea.

Starch readily gelatinizes (or disperses) in hot water to form a paste that can be cast into film. Unfortunately, the films are sensitive to water and become quite brittle upon drying. To alter these properties, starch is generally blended with biodegradable plasticizers and additives. The basic problem with starch biopolymers centers around the influence of water during processing and the post-processing stability of materials when the water content changes.

NOVON Products, a division of the Warner Lambert Company, has been able to overcome many of these difficulties by blending specialty starches from potatoes and/or corn, in a patented process with other completely biodegradable additives. Like polylactic acid and PHBV polymers, NOVON resins are relatively more expensive than petroleum-based resins [11]. Nevertheless, NOVON has obtained some market success:

- Jafra Cosmetics uses biodegradable starch-based loose-fill cushioning made from NOVON polymers to ship its mail-order cosmetics and personal-care products,
- Storopack Inc., uses NOVON resins to manufacture a water-dispersible loose-fill that can replace polystyrene "peanuts,"

- Terraform Company uses NOVON resins to produce golf tees now stocked by K-mart,
- Biku-Form uses NOVON resins to manufacture votive candle cups, and
- Bio-Bags and Film uses NOVON resins to make film bags for composting.

The properties, costs, and producers of biodegradable polymers currently on the market are in appendix table 1.

Where Do Biodegradable Polymers Fit in the Plastics Industry?

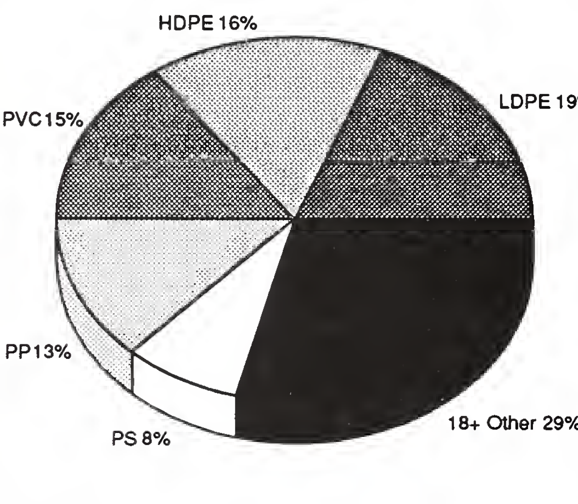
Biodegradable polymers compete in the plastic materials and resins markets. The output from this industry includes commodity resins such as high-, low-, and linear-low-density polyethylene; polypropylene; polystyrene; polyvinyl chloride; and polyethylene terephthalate. Between 1987 and 1992, the value of shipments for the overall industry grew from $26.2 billion to an estimated $31.4 billion. Based on constant 1987 dollars, this translates into a 4.6-percent real annual increase [14].

Approximately 65.4 billion pounds of resins were produced in 1992. Low-density polyethylene (LDPE) captured 19 percent of the 1992 market; high-density polyethylene (HDPE), 16 percent; polyvinyl chloride (PVC), 15 percent; polypropylene (PP), 13 percent; polystyrene (PS), 8 percent; and more than 18 additional materials account for the remaining 29 percent (figure A-1). Of the remaining 29 percent, degradable polymers have captured less than 5 million pounds of the resins market.

Plastic's durability and indestructibility make it best for many applications. Nevertheless, environmental concerns, both of pollution from production processes and of solid waste disposal of end-use products, have forced the plastics industry to look for raw material substitutes and for improvements in the recyclability and biodegradability of end-use products.

Figure A-1

U.S. Plastic Sales, 1992



Source: Modern Plastics, January 1993.

The bottom line is that recycling should be done whenever possible. However, in those cases where recycling is ineffective or impossible, biodegradability becomes an issue. Four markets are targeted for biodegradable polymer applications: food packaging, nonfood packaging, personal and health care, and other disposables. Degradable food packaging will not be addressed in this article because the Food and Drug Administration (FDA) has not yet established guidelines for its use. For that reason, nonfood packaging will be taken as the key market.

How Big Is the Potential Market?

The single-use items slated for replacement are manufactured from a few classes of commodity resins. These include high- and low-density polyethylene, polypropylene, polystyrene, polyethylene terephthalate, and polyvinyl chloride. Of the 16.5 billion pounds of plastics used in packaging in 1992, various forms of polyethylene and polystyrene accounted for 62.4 percent or 10.3 billion pounds.

In 1992, total sales of low-density polyethylene (LDPE) reached 6.9 billion pounds (table A-1). If one assumes that half the miscellaneous packaging market represents nonfood packaging, then the total LDPE nonfood packaging market is 2.68 billion pounds. In addition, the trash bag market, a major target for biodegradable polymers, accounted for 1.4 billion pounds. Smaller markets for which some penetration might be possible include diaper backing, 0.24 billion pounds, and agriculture, 0.22 billion pounds.

In comparison, total 1992 sales of high-density polyethylene (HDPE) were 10.4 billion pounds. HDPE is used to produce durable products and so is not as amenable to biodegradable polymers as the LDPE market. However, there are some potential applications: nonfood bottles, films and sheeting, and consumer packaging (table A-2) [7]. Therefore, if biodegradable polymers were to replace low-density polyethylene and high-density polyethylene in selected nonfood packaging uses, the potential market would be approximately 8 billion pounds annually.

Table A-1--Low-density polyethylene use, 1992

Market	Million pounds
Nonfood packaging	2,439
Trash bags	1,432
Food packaging	1,158
Miscellaneous packaging	563
Miscellaneous nonpackaging	354
Industrial sheeting	245
Diaper backing	242
Agricultural	221
Household wrapping	183
Nonwoven disposables	57
Total	6,894

Source: Modern Plastics, selected years.

How Will Biodegradable Polymers Affect the Farm Sector?

In 1992, biodegradable polymer resins captured less than 5 million pounds or roughly .08 percent of the resins market. Provided that Congress does not mandate increased biodegradable polymer use, market penetration into the 8-billion-pound, single-use plastics market described above will likely be slow. Consequently, this analysis uses conservative scenarios.

The low-growth scenario is based on estimates from the Institute for Local Self-Reliance (ILSR). ILSR expects the demand for biodegradable polymers to double between 1991 and 1995. This would put total demand at roughly 8.4 million pounds of resin in 1995. The moderate-growth scenario is based on projections by the Business Communications Company (BCC) of Norwalk, CT. BCC expects natural plastic use to reach 1.2 billion pounds by 2002. Table A-3 shows the yearly demand for biodegradable polymers starting from a base of 5 million pounds in 1992, and applying these two growth scenarios.

How will higher biopolymer production increase the demand for agricultural commodities? The analysis explicitly assumes that cornstarch technologies will capture the lion's-share of this market. This simplifies the analysis, recognizing that all of the technologies mentioned above use or could use corn, wheat, or potato starch for production. Furthermore, since many of the inputs used to produce biodegradable polymers are highly substitutable, there would be positive feedback effects in each related market. So, the choice of substrate is not crucial.

Wet milling corn yields 33 to 35 pounds of starch per 56-pound bushel of corn. Multiplying the number of pounds of resin by the percentage of cornstarch used in a particular technology gives an estimate of the number of pounds of cornstarch needed. Then, dividing the number of pounds of cornstarch by 34 gives an estimate of the number of bushels of corn used. Table A-4 translates the resin projections in table A-3 into bushels of corn, assuming technologies that use, on average, 25-, 50-, and 75-percent cornstarch.

The final step simulates the effect of increased biopolymer producion on farmers and farm subsidies. The Food and Agricultural Policy Simulator (FAPSIM) has been developed and refined at ERS for over 10 years, simulating the effects of various farm policy decisions on farmers and farm subsidies. FAPSIM estimates a simultaneous price-quantity equilibrium solution for a set of individual commodity models developed for beef, pork, dairy, chickens, eggs, turkeys, corn, oats, barley, grain sorghum, wheat, rice, soybeans, and cotton. FAPSIM also endogenously determines farm production expenses, cash receipts, net farm income, government deficiency payments and reserve storage payments, plus farmer participation in government commodity programs [12].

FAPSIM includes the level of farmer participation in government commodity programs to develop acreage response equations for corn, wheat, and other program crops. Therefore, the acreage response relationships contained in FAPSIM reflect the relative profitability of either participating or not participating in a government commodity program. Here, the model's estimates can be used to determine how increased biopolymer production will affect overall farm profitability and government program payments.

Based on industry estimates of starch-loading between 25 and 90 percent, this analysis simulates the 50 percent loading scenario. The FAPSIM simulations measure the difference between the baseline projection for each year, given the 1990 Farm Bill, against the low- and moderate-growth scenarios. The only thing changed between the baseline projection and the FAPSIM simulations is the introduction of increased production of cornstarch-based biodegradable polymers.

Table A-2--High-density polyethylene use, 1992

Market	Million pounds
Nonfood bottles	1,447
Film and sheeting	1,187
Consumer packaging	905
Total	3,539

Source: Modern Plastics, selected years.

Table A-3--Two market scenarios of biodegradable polymer growth, 1993-2000

Year	Low growth	Moderate growth
	--Million pounds of resin--	
1993	5.9	8.6
1994	7.1	14.9
1995	8.4	25.8
1996	10.0	44.7
1997	11.9	77.3
1998	14.1	133.6
1999	16.8	231.0
2000	20.0	399.3

Table A-4--Corn utilization, 1994-2000, with two biopolymer growth scenarios

Year	Percent starch loading 25	50	75
	--1,000 bushels of corn--		
Low growth scenario			
1994	51.98	103.95	155.93
1996	73.48	146.96	220.43
1998	103.88	207.76	311.63
2000	146.85	293.71	440.56
Moderate growth scenario			
1994	109.91	219.81	329.72
1996	328.56	657.11	985.67
1998	982.20	1,964.41	2,946.61
2000	2,936.24	5,872.47	8,808.71

As shown in appendix table 2, an increase in cornstarch-based biodegradable polymers has little effect. Total feed grain and corn supplies increase marginally. Industrial uses for feed grains and corn reflect primarily the increased use of corn for biopolymer production, however some substitution between grains appears to exist. Also, the average market price for corn does not change in the low-growth scenario, and changes slightly in the moderate-growth scenario.

Under both scenarios, corn deficiency payments go down and total deficiency payments, including corn payments, decrease further. This suggests that there is some substitutability in the starch market, so the choice of substrate is probably not critical from a policy perspective. Finally, in both scenarios, net farm income increased, reflecting primarily the higher cash receipts associated with higher corn prices.

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Appendix table 1. Some properties and producers of biodegradable polymers 1/

Company (plastic type)	Price per lb. of resin	Maximum use temperature (centigrade)	Specific gravity (times heavier or lighter than water)	Base properties	Applications	Bio-degradability
NOVON resins (starch-based)	$1.50-3.00	170-200	1.40-1.45	Water soluble, suitable for injection molding.	Pharmaceutical capsules, packaging materials like "peanuts," golf tees, candle stands, fast-food cutlery, films.	Very high
ICI resins (sugar-based PHBV)	$8.00-10.00	110-180	1.25	Good shelf stability, suitable for injection and blow molding.	Shampoo bottles, disposable razors, injection-molded articles.	High
Battelle polymers (polylactic acid)	$1.00-2.00	120-170	1.20-1.40	Excellent molding properties. Copolymerized with glycolic acid and other plant-based polymers.	Commodity plastics for molding applications, controlled release of agrichemicals and drugs.	Very high
FLEXEL cellulose resins (cellulose films)	$2.40-3.60	60-100	1.10-1.30	Excellent film-forming properties. Flexible. Good mechanical strength.	Sandwich bags, packaging films, uncoated clear films.	High
Mater-Bi Novamont/Feruzzi	$1.60-2.50	150-200	1.32-1.45	Contains at least 60% starch and other biodegradable materials. Excellent molding and film-extrusion properties.	Disposable diapers, high heat-aging resistant films, moldable article applications.	High
Ecochem (polylactides)	$2.00-2.50	130-150	1.20-1.40	Recyclable polylactide. Completely compostable. Good extrusion properties and film formation.	Packaging film and sheets.	High

1/ Source: Morris, David and Irshad Ahmed. *The Carbohydrate Economy: Making Chemicals and Industrial Materials from Plant Matter.* Washington, DC; The Institute for Local Self-Reliance, 1992.

Appendix table 2: FAPSIM difference from baseline projections

			Low-growth scenario		Moderate-growth scenario	
			Sum	Average	Sum	Average
Total feed grains						
	Total supply	Mil. metric tons	0.007	0.001	0.065	0.008
		% change[1]	0.001	0.000	0.020	0.003
	Industrial use	Mil. metric tons	0.032	0.004	0.325	0.041
		% change	0.065	0.008	0.623	0.078
Corn						
	Total supply	Mil. bushels	0.291	0.036	2.313	0.289
		% change	0.001	0.000	0.021	0.003
	Industrial use	Mil. bushels	1.298	0.162	12.793	1.599
		% change	0.074	0.009	0.715	0.089
	Average market price	Dollars/bushel	0.000	0.000	0.012	0.002
		% change	0.000	0.000	0.487	0.061
Corn income factors						
	Value of production	Mil. dollars	10.995	1.374	116.002	14.500
		% change	0.052	0.007	0.524	0.066
	Deficiency payments	Mil. dollars	-5.000	-0.625	-45.03	-5.629
		% change	-0.221	-0.028	-2.120	-0.265
Total deficiency payments[2]		Mil. dollars	-5.819	-0.727	-51.528	-6.441
		% change	-0.103	-0.013	-0.954	-0.119
Net farm income		Mil. dollars	6.000	0.750	30.00	3.750
		% change	0.010	0.001	0.054	0.007

[1]The percentage change numbers are a non-weighted cumulative average. This gives a rough approximation of the percentage change over the simulation period, 1993-2000.

[2]Deficiency payments for all other crops in Federal programs either went down or did not change.

Ethanol's Evolving Role in the U.S. Automobile Fuel Market

by

Hyunok Lee

Abstract: *Fuel ethanol in the United States is now predominately made from corn. However, future sources may include cellulosic materials, such as short-rotation woody and grass crops. Once considered a simple fuel extender, ethanol also is used as an octane enhancer and oxygenate. Provisions of the 1990 Clean Air Act Amendments, aimed at controlling carbon monoxide and ozone, are opening up new markets for ethanol. This article investigates the supply and demand for ethanol and compares ethanol prices with its main oxygenate competitor, MTBE.*

Keywords: Ethanol, renewable fuels, corn, oxygenates.

The idea of using alcohol as an automotive fuel is not new. The first modern combustion engine, the Otto Cycle, burned alcohol in 1876, and Henry Ford ran his 1908 Model T on alcohol, gasoline, or a mixture of the two. The major commercialization of fuel ethanol in the United States, however, did not occur until the 1970's.

The decade marked events critical to the ethanol industry, including two oil crises, the Soviet grain embargo, the passage of the 1977 Clean Air Act, and the 1978 Energy Tax Act. Conditions created by those events, such as high oil prices, an abundant corn supply, the phaseout of lead from gasoline, and Federal/State ethanol incentive programs, encouraged the growth of the U.S. industry.

Since the late 1970's, ethanol has been used as a gasoline extender by generally blending one part of ethanol with nine parts of gasoline to produce "gasohol." During the same time, the Environmental Protection Agency (EPA) was looking for a replacement for lead in gasoline. Because of its high octane content, ethanol emerged as a potential candidate.

In recent years, interest in ethanol has centered around its use as an oxygenate to help reduce automobile air pollution. Provisions of the 1990 Clean Air Act Amendments (CAAA) established the Oxygenate Fuels Program and the Reformulated Gasoline Program in an attempt to control carbon monoxide (CO) and ground-level ozone problems. Both programs require certain oxygen levels in gasoline: 2.7 percent by weight for oxygenated fuel and 2.0 percent by weight for reformulated gasoline.

Ethanol Production Capacity Is Over 1 Billion Gallons

Ethanol, also known as ethyl alcohol, can be produced from any source of fermentable sugars including starch, cellulose, and hemicellulose. Agricultural/forestry products and energy crops, as well as agricultural residues, provide a wide variety of biomass feedstocks for ethanol. The most predominant feedstock in the United States is corn, which is used to produce about 95 percent of U.S. ethanol. In 1992, domestic ethanol producers used 400 million bushels of corn, which accounted for over 5 percent of the 1991/92 U.S. corn crop (7,475 million bushels). During the same year, corn used for ethanol production was equal to about 25 percent of U.S. exports (1,584 million bushels).

Ethanol production has grown from 20 million gallons in 1979 to almost 1 billion gallons in 1992. Today, annual production capacity is estimated at about 1.1 billion gallons per year. The industry is expanding as new producers, such as Cargill (operating a new 28-million-gallon plant), enter the market. Construction currently underway will add another 690 million gallons of annual capacity.

The U.S. ethanol industry is highly concentrated. In 1992, 34 ethanol plants were operating in the United States. Of these, 16 have production capacities of over 10 million gallons per year, and together they account for 90 percent of total capacity. The industry giant, Archer Daniels Midland, controls nearly 70 percent.

Ethanol can be made from corn through dry milling or wet milling. Dry mills produce ethanol on a year-round basis, while several wet mills shift production to high fructose corn sweeteners when demand for sweeteners is high. Wet milling accounts for about 60 percent of total ethanol production. Compared to dry milling, it is capital-intensive, but compatible with new technologies such as producing starch for biodegradable polymers.

With current technologies, a bushel of corn from wet milling yields 2.5 gallons of ethanol, 12.4 pounds of 21-percent protein feed, 3 pounds of 60-percent gluten meal, and 1.5 pounds of corn oil. Dry milling yields 2.6 gallons of ethanol and 18 pounds of distillers' dried grains and solubles. In addition, both processes yield carbon dioxide, which is sold primarily to the soft drink industry. While wet milling attains slightly lower ethanol yields per bushel of corn, wet-milling coproducts are worth more than those from dry milling, as much as 30 to 50 cents per bushel of corn.

Production costs vary greatly from plant to plant, depending on plant efficiency, economies of scale, and coproduct revenues. Cost-reducing innovations in the last 5 years have emerged mainly in the areas of energy and ingredient uses and computerized control. Cogeneration facilities--plants that use the energy generated as a result of processing--now

considerably reduce the energy costs of converting corn to ethanol. Also, new or improved organisms for prefermentation/fermentation speed up processing time and reduce capital costs. Automated operations have been a major source of labor cost savings.

Oxygenates Mean a New Market Environment

Until recently, the petroleum industry viewed ethanol as a product that could dilute gasoline demand, and ultimately, market share. But recently, refiners have begun to negotiate with ethanol producers on long-term contracts to ensure the continuous supply of oxygenates. As they provide necessary components for oxygenated fuel, major oil companies have reentered the ethanol business. Chevron, Shell, and Marathon today blend ethanol into their gasolines because it is a cost-effective way to meet clean air regulations.

The general mood of automobile manufacturers toward ethanol also is changing. In the late 1970's and early 1980's, the automotive industry was one of the major constraints preventing ethanol from penetrating the fuel market. Now, all auto manufacturers approve the use of ethanol-blended gasoline under their warranties. Some manufacturers, such as General Motors, actively encourage the use of ethanol blends by recommending oxygenated fuels in their 1990 owners' manual.

Low-Cost Feedstocks May Be Future Sources of Ethanol

Research to further lower production costs is under way. Improvements in membrane technology, bacterial fermentation, and coproduct development are being discovered [1]. Most important, there is considerable on-going research developing potentially low-cost feedstocks, including short-rotation woody crops, such as hybrid poplar, and herbaceous energy crops, such as switchgrass. These types of energy crops can be grown on a wide range of lands and in a variety of climates, and herbaceous crops can be harvested 1 to 3 times a year.

The cellulose and hemicellulose in wood and grass can be converted to sugars and then fermented to ethanol. The Department of Energy (DOE) is pursuing intensive development of energy crops under the Department's Biofuels Program. USDA is working with DOE to facilitate joint research efforts in feedstock development, conversion techniques, environmental and economic considerations, coproduct development, utilization, and testing.

While the expansion potential of corn-based ethanol may ultimately be constrained by limits on corn production, the use of cellulosic biomass has the potential to supply a significant portion of U.S. gasoline consumption. Some early cost estimates have been made for using cellulosic feedstocks. Successful research and development has reduced the estimated cost from over $2 per gallon to around $1.22. This is only slightly above corn-based ethanol at current corn prices. Further efforts to bring down production costs are underway. However, many difficulties--such as seed supply for energy crops, educating farmers to grow nonconventional crops, and developing a production strategy specific to each crop--still must be overcome.

Ethanol Was First Used as a Gasoline Extender

To provide economic incentives to ethanol producers in the 1970's, Federal and State governments initiated support programs, such as tax incentives and loan programs. Federal tax exemptions were initiated under the Energy Tax Act of 1978 by giving the minimum 10-percent ethanol blend a 4-cent-per-gallon exemption from the Federal gasoline excise tax [2].

Along with an increase in the Federal gasoline tax from 4 to 9.1 cents per gallon in 1983, ethanol-blend tax exemptions were raised to 5 cents per gallon and, subsequently, to 6 cents. Since January 1991, the current tax exemption has been set at 5.4 cents per gallon of 10-percent ethanol blends and extended until 2000. The minimum 10-percent-blend requirement translates into an effective 54-cent tax exemption per gallon of ethanol, and the exemption is provided through the Highway Trust Fund.

Beginning December 31, 1992, proportional excise tax exemptions are provided for alcohol-blended fuels at 7.7 and 5.7 percent by volume. These rates correspond to the oxygen content requirements of 2.7 and 2.0 percent by weight under Title II of the CAAA. Tax exemptions are typically taken at the wholesale level. A gasoline wholesaler purchasing fuel to be blended with ethanol at 10 percent pays 8.6 cents per gallon rather than the full 14 cents per gallon Federal gasoline excise tax. The same exemption process applies to the 4.2- and 3.1-cent tax exemptions available for 7.7- and 5.7-percent ethanol blends.

The Federal government has also encouraged ethanol industry development in other ways. In 1978, the Federal government authorized $1.2 billion in loan guarantees to finance alternative fuel investment projects, including ethanol and methanol production from renewable sources. These Federal programs also extended to the research and development of ethanol technology. Since the 1973 Arab oil embargo, more than $40 million has been allocated to alcohol fuel research.

States have also assisted ethanol producers by providing gasoline sales tax exemptions and/or direct payments to producers. Historically, sales tax exemptions were widely used as an incentive program, but are no longer the only mechanism employed in developing new ethanol markets. By the end of 1980, 25 States exempted 10-percent blends from all or part of State gasoline sales taxes, and the initial State exemptions were estimated on average as 30 cents per gallon. During the 1980's, due to budget problems and little in-state ethanol production, many States eliminated or curtailed exemptions.

Recently, with renewed interest in ethanol prompted by the CAAA, some States, such as Oregon and Illinois, have been moving toward initiating or renewing State tax incentives. Presently, 12 States make partial sales tax exemptions available and only one, Alaska, grants full exemption (table

B-1). Most also allow proportional excise tax exemptions for 7.7- and 5.7-percent blends.

State-sponsored producer incentives apply if certain qualified feedstocks (produced within the State), fuel sources, plant capacities, or processing techniques are used. Generally, payments are made directly to ethanol producers. Direct producer incentives stimulate investment in new plants and equipment and, in some cases, have given small producers a competitive advantage within the State. Currently, seven States provide direct producer payments ranging from 20 to 40 cents per gallon.

Because ethanol mixes with water, pipeline transportation is difficult without some level of maintenance. Therefore, it is usually not blended with gasoline at the refinery but by local wholesalers when they deliver to gas stations. Ethanol producers have often offered ethanol at discounted prices and allowed blenders a margin to encourage them to use ethanol as a blending agent.

The market share of ethanol-blended gasolines has increased from virtually nothing to over 8 percent of all gasolines today. This implies that ethanol displaces about 1 percent of conventional gasoline consumption, since ethanol is blended mostly at 10 percent.

Ethanol Enhances Octane Levels

Other government actions, although not targeted to enhance ethanol use, have greatly influenced the industry. In the late 1970's, EPA initiated a public information and education campaign to remove lead from gasoline. At the time, lead was used to increase octane content. One easy alternative to boost octane content was to blend gasoline with a high-octane alcohol such as ethanol. When ethanol is blended with gasoline at a rate of 10 percent, it raises the fuel's octane level by an average of 3 octane points.

The octane rating is a measure of a fuel's ability to resist knock and ping in gasoline engines. A typical grade of unleaded gasoline has an octane rating of 87 and premium unleaded gasoline has a rating of 91 to 93, while pure ethanol has a rating of 113. Ethanol-blended gasoline is sold in the fuel market as regular unleaded or as super unleaded. Automobile users increasingly are demanding high-octane gasoline and, at the same time, automobile manufacturers are once again producing numerous high-performance engines that can take advantage of higher octane gasoline. As a result, refiners will continue to search for octane sources at the lowest possible cost.

Methyl tertiary butyl ether (MTBE), which was developed primarily as an octane enhancer, has an octane rating of 110. First produced as a fuel additive in 1979, MTBE has become a popular blending agent and oxygenate. Ether products such as MTBE can easily be blended with gasoline at the refinery and transported by pipeline.

Ethanol Can Help Meet the Demand for Oxygenates

The key chemical property that differentiates ethanol from gasoline is the presence of oxygen. Ethanol can be used as an oxygenate to help control both carbon monoxide and ozone pollution.

Carbon Monoxide. The CAAA calls for the use of oxygenated fuels in the Oxygenated Fuels Program, beginning in November 1992, to control carbon monoxide problems. CO in urban atmospheres comes primarily from the exhaust emissions of internal combustion engines, such as those in most cars and trucks. The presence of oxygen in the fuel raises the effective air-to-fuel ratio for more complete combustion and reduces carbon monoxide emissions.

Title II of the CAAA designates 39 regions in the Nation as CO nonattainment areas. To meet CAAA regulations, re-

Table B-1--State gasoline taxation and ethanol incentives, March 1993

State	Gasoline tax	Ethanol incentive: Reduction in tax	Ethanol incentive: Direct producer payments 1/
	--Cents per gallon--		
Arkansas	8.0	8	--
Connecticut	23.0	2/ 1	--
Hawaii	19.4	3/	--
Illinois	24.5	4/	--
Iowa	20.0	1	--
Ohio	21.0	5/ 1.5	--
Oregon	20.0	6/ 5	--
Washington	22.0	3.7	--
Wyoming	9.0	4	--
Minnesota	20.0	2	20
South Dakota	18.0	2	20
Missouri	11.0	2	20
Kansas	16.0	--	20
Montana	20.0	--	30
Nebraska	23.9	--	20
North Dakota	17.0	--	40

-- = Not applicable.

1/ Only for ethanol produced in the State. 2/ Ethanol or methanol, 10 percent by volume. 3/ 4-percent reduction from existing tax imposed on retail sale of ethanol blends. 4/ 2-percent reduction from existing tax imposed on retail sale of ethanol blends. 5/ Tax credit expires September 30, 1993. 6/ Effective January 1, 1992.

Source: Alcohol Outlook, March 1993.

finers and blenders must use oxygenates, including ethanol, MTBE, or other ethers such as ethyl tertiary butyl ether (ETBE), tertiary amyl ethyl ether (TAEE), or tertiary amyl methyl ether (TAME). MTBE, the most widely used oxygenate in the market today, and TAME are methanol-based ethers derived primarily from natural gas. ETBE and TAEE are ethanol-based ethers.

The CAAA mandate that gasoline sold in all 39 CO nonattainment areas for at least 4 winter months should contain 2.7 percent oxygen by weight at a minimum, unless a State chooses to adopt an averaging program or places a cap on the oxygen content [3]. Some of the worst CO problem areas--such as Denver, Phoenix, and Tucson--required oxygenated fuels during winter months even before the Oxygenated Fuels Program became mandatory.

Ethanol has a higher oxygen content than MTBE, 35 percent versus 18 percent by weight. Therefore, the 2.7-percent oxygen requirement dictates a 15-percent MTBE blend, a 7.7-percent ethanol blend, or a 17-percent ETBE blend.

Ozone. Ground-level ozone is a greenhouse gas that contributes to global warming and human health problems. In urban areas, ozone is created from ultraviolet light acting on local concentrations of volatile organic compounds (VOC's), CO, and nitrogen oxides (NOx). VOC's result from the evaporation of gasoline and other solvents and from vehicle exhaust. NOx mainly come from burning fossil fuels, including gasoline and coal.

Beginning in January 1995, the nine worst ozone nonattainment areas designated in CAAA Title II--the regions of Los Angeles, New York, Hartford, Baltimore, Philadelphia, Chicago, Milwaukee, Houston and San Diego--are required to sell reformulated gasoline year-round. In addition, the CAAA designated 87 other regions as ozone nonattainment areas. The CAAA allows these areas to opt in voluntarily to the Reformulated Gasoline Program. Almost half of the U.S. population lives in the ozone nonattainment areas designated by the CAAA.

The CAAA requires a certified reformulated gasoline to reduce emissions of ozone-forming VOC's by 15 percent compared to the 1990 reference fuel. The central problem with ethanol is that current ethanol blends increase volatility, thereby increasing VOC emissions caused by fuel evaporation. For example, 10-percent ethanol blends boost volatility by 1 pound per square inch (psi).

Ethanol is expected to play a role in the reformulated gasoline market to the extent that the program requires 2.0 percent oxygen by weight in gasoline. However, how the volatility issue will be resolved is uncertain until the rules and regulations for the Reformulated Gasoline Program are completed.

Volatility is not a problem associated with all ethanol blends. The first few percent of ethanol added to gasoline will increase volatility measured in terms of the Reid vapor pressure (RVP). However, the low volatility of ethanol compared to regular gasoline begins to dominate when the blending rate reaches around 20 to 40 percent. Volatility further declines to a RVP of 2.3 psi for 100 percent ethanol, compared to 9 psi for regular gasoline and 7.8 psi for MTBE.

ETBE blends can meet and surpass the reformulated gasoline requirements because ethers have a low vapor pressure. In the future, more ethanol may be used as a feedstock for ETBE and TAEE. Natural gas-based methanol has a current economic advantage over ethanol as an ether feedstock because of its lower price. But the low vapor pressure of ETBE blends--3 to 5 psi compared with 9 to 10 psi for MTBE blends--may offset that price disadvantage in the future when more strict RVP regulations are imposed.

In addition, research addressing ethanol's volatility problem continues. Activities include VOC emission reduction strategies, such as co-solvent and azeotrope research to mitigate ethanol's RVP effects, and emission testing on mixed alcohol and ether blends.

Future Demand Looks Promising

The net effects of the CAAA are promising new market opportunities for ethanol. Near-term demand will come as a blending component in gasoline, but ethanol's future potential exists as a feedstock for ethers as well as an alternative fuel.

The initial increase in demand for ethanol will come from CO nonattainment areas to meet the oxygenate requirements. During 1992, ethanol consumption reached nearly 1 billion gallons and MTBE consumption exceeded 2 billion gallons. According to American Petroleum Institute estimates, the oxygenate demand from CO nonattainment areas during 1992/93 will be almost twice the pre-program level.

Prior to 1995, ethanol demand depends primarily on the scale of the gasoline market in CO nonattainment areas, the length of the CO season, and the transportation economics of moving oxygenates from attainment areas to nonattainment areas.

Beginning in 1995, the demand for oxygenates will expand further to meet the 2-percent-oxygen requirement for reformulated gasoline. The magnitude of the expansion in demand will largely depend on how many of the ozone nonattainment areas opt into the program. Around 20 percent of U.S. gasoline demand is in the nine worst ozone nonattainment areas. If all eligible areas opt in, 70 percent of gasoline consumption would be in reformulated markets. The opt-in decision is voluntary and will be greatly affected by the oxygenate market that exists at the time the decision is made.

Nearly pure ethanol--85 to 95 percent--holds promise as an alternative fuel for dedicated or flexible fuel vehicles [4]. The Alternative Motor Fuels Act of 1988 and the clean fuel and fleet provisions of the CAAA add impetus to reducing imported and petroleum-based transportation fuels by promoting alternative fuels. The Comprehensive National Energy Policy Act of 1992 also includes provisions to help develop alternative fuels.

Competing with MTBE

Market demand for ethanol in the oxygenate market depends on the supply of ethanol's principal competitor, MTBE. Many chemical companies and major refiners are planning MTBE production or expansion. The United States is currently the world's leading MTBE producer, with 1.9 billion gallons of capacity, which is expected to more than double by 1994.

Future MTBE production depends greatly on feedstock availability. As domestic production grows in response to increased demand for oxygenates, a substantial portion of MTBE feedstocks, methanol and butylene, may have to be imported. Even now, about one-quarter of the methanol consumed in the United States comes from abroad.

Because all oxygenates are also octane enhancers, their prices generally reflect the value of both uses. In the past, the upward trend of MTBE prices--from 67 cents per gallon in 1987 to 97 cents in 1990--may have been partly due to its octane value, which can be priced at about 1.25 cents per octane number at the wholesale level. Unlike MTBE, ethanol's octane value has not been fully realized in its price. During the same period, ethanol prices ranged from $1.28 per gallon in August 1987 to $1.06 in January 1988.

In the past, the value of ethanol has been derived mostly from its role as a gasoline extender. Now, with oxygenated fuel use mandated by the CAAA, the oxygen value of ethanol will likely be an important factor in its pricing. To examine the oxygen value of ethanol, MTBE-compatible ethanol prices were calculated for given prices of MTBE and regular gasoline (table B-2).

A MTBE-equivalent ethanol price represents a threshold ethanol price at which a gasoline blender is economically indifferent between MTBE and ethanol as a choice of oxygenate. This exercise mainly investigates how ethanol prices may change with the prices of MTBE and gasoline.

To meet the minimum 2.7-percent-oxygen-by-weight requirement, a gallon of oxygenated gasoline can be either an ethanol blend, 10-percent ethanol with 90-percent gasoline, or a MTBE blend, 15-percent MTBE with 85-percent gasoline. (Even though only a 7.7-percent ethanol blend could meet the requirement, the 10-percent blend was used in the calculations because the 10-percent blend will more likely be used to maximize the tax benefits.)

For a given price of oxygenated gasoline, the economic choice of oxygenate depends on the gasoline price, as well as the price of the oxygenate. As gasoline price rises, there will be an incentive to shift to MTBE because the MTBE blend uses less gasoline than the ethanol blend. When gasoline prices are falling, the shift will be to ethanol.

For example, when MTBE is 80 cents and gasoline is 60 cents per gallon, a gallon of MTBE oxygenated gasoline would be sold at 63 cents (80 cents x 15 percent + 60 cents x 85 percent). The MTBE-equivalent ethanol price is calculated using the computed oxygenated gasoline price, 63 cents, and the predetermined regular gasoline price, 60 cents. The MTBE-equivalent ethanol price, 90 cents, would produce an ethanol oxygenated gasoline at 63 cents per gallon (90 cents x 10 percent + 60 cents x 90 percent).

Another interpretation of the MTBE equivalent ethanol price can be made. Given prices of MTBE and gasoline at 80 and 60 cents per gallon, respectively, the highest price at which ethanol could be sold in the marketplace would be 90 cents, assuming that MTBE leads the price of oxygenates and ethanol blending and handling costs are zero.

Ethanol blends usually incur additional costs in transportation, blending, and possibly a margin for the blender. Therefore, the actual MTBE-compatible ethanol price would be lower by these additional costs. Using the earlier example, when the MTBE-compatible ethanol price is 90 cents, the actual market price of ethanol would be 80 cents per gallon, assuming 10 cents of additional costs.

Ethanol also receives Federal and State (if available) excise tax exemptions. These tax benefits would be reflected in the ethanol price by raising the market price of ethanol by the amount of tax exemption. Following the example, adding the Federal exemption of 54 cents per gallon would bring the price up to $1.34 (80 cents + 54 cents). State exemptions would further increase the value of ethanol.

Notes and References

1. Neil Hohmann and Matthew Rendleman. *Emerging Technologies in Ethanol Production*. USDA, ERS, Agricultural Information Bulletin 663, January 1993.

Table B-2--MTBE-equivalent ethanol price 1/

	--Dollars per gallon--				
Gasoline	MTBE prices				
prices	.80	.90	1.00	1.10	1.20
.50	2/ 0.95 (.55)	1.10 (.56)	1.25 (.57)	1.40 (.59)	1.55 (.60)
.60	0.90 (.63)	1.05 (.64)	1.20 (.66)	1.35 (.67)	1.50 (.69)
.70	0.85 (.72)	1.00 (.73)	1.15 (.74)	1.30 (.76)	1.45 (.77)
.80	0.80 (.81)	0.95 (.82)	1.10 (.83)	1.25 (.84)	1.40 (.86)

1/ A similar calculation was presented in Oxy-Fuel News, May 27, 1991. 2/ Numbers in parentheses are the prices of oxygenated gasoline, using either MTBE or ethanol.

2. A fixed exemption was granted for all ethanol blends, 10 percent and above. This effectively eliminates any blends above 10 percent from the market, because with no tax incentive above 10 percent, it is not economical to replace gasoline with more expensive ethanol.

3. States have the option of adopting a per-gallon program or an averaging program. Averaging permits industry to use marketable oxygen credits for gasolines with a higher oxygen content than required to offset the sale or use of gasolines with a lower oxygen content. Averaging programs are a cost-effective wayof implementing the Oxygenated Fuels Program because averaging allows the market additional flexibility and full utilization of valuable oxygenates. A State also can impose a limit or cap on the oxygen content of oxygenated gasoline, if EPA approves the cap is necessary. For instance, California currently imposes a cap at 1.8 to 2.2 percent oxygen by weight.

4. Pure, 100-percent ethanol is legally prohibited from being used as a fuel according to the Bureau of Alcohol, Tobacco, and Firearms. Thus, all alcohol fuels must be denatured by mixing them with toxic substances such as gasoline.

List of Tables

Table 13--Current utilization and projected potential of plant matter in producing intermediate chemicals and industrial materials in the United States, estimated by the Institute for Local Self-Reliance

Product	Total 1992 production	Plant matter-derived 1/	Plant matter-derived 1996 potential	Conventional product costs	Plant matter product costs 2/	Reduction in plant matter product costs since 1985	Reduction in plant matter product costs by 1996 3/
	Million tons	--Percent--		--Dollars/pound--		--Percent--	
Wall paints	8.0	3.5	10.0	0.50	1.20	14.0	20.0
Special paints	2.5	2.0	4.0	0.80	1.75	3.0	5.0
Pigments	15.5	4.0	6.0	2.00	5.80	20.0	15.0
Dyes	4.5	6.0	15.0	12.00	18.00	25.0	20.0
Inks	3.6	8.0	17.0	2.00	2.40	30.0	10.0
Detergents	3.8	12.0	18.0	1.20	1.50	15.0	5.0
Surfactants	3.9	39.0	50.0	0.45	0.45	20.0	5.0
Adhesives	5.1	42.0	48.0	1.65	1.40	15.0	2.0
Poymers	30.3	3.4	7.0	0.50	2.00	20.0	45.0
Plasticizers	0.9	15.0	32.0	1.50	2.50	20.0	20.0
Acetic acid	1.8	16.0	24.0	0.33	0.35	5.0	2.0
Furfural derivatives	0.3	25.0	35.0	0.75	0.78	10.0	2.0
Fatty acids	2.5	40.0	55.0	0.46	0.33	5.0	5.0
Industrial carbon	1.5	12.0	19.0	0.50	0.45	10.0	15.0

1/ Represents both wholly and partially plant-matter-derived products. 2/ The cost premium of plant matter-based products is calculated based on the average median costs of commercially available products in a given category. 3/ Market projections based on performance over the past 5 years and the expected contributions of recent technical breakthroughs.

Source: David Morris and Irshad Ahmed, The Carbohydrate Economy: Making Chemicals and Industrial Materials from Plant Matter. Washington, DC; Institute for Local Self-Reliance 1992, revised June 1993.

Table 14--Flaxseed, acreage planted, harvested, yield, production, and value, 1985-92

Year	Planted	Harvested	Yield	Production	Value
	--1,000 acres--		Bushels per acre	1,000 bushels	$1,000
1985	620	584	14.2	8,293	41,912
1986	720	683	16.9	11,538	39,962
1987	470	463	16.1	7,444	25,188
1988	275	226	7.1	1,615	12,200
1989	195	163	7.5	1,215	8,724
1990	260	253	15.1	3,812	21,108
1991 1/	351	337	18.1	6,100	21,395
1992 2/	191	182	16.0	2,912	14,123

1/ Preliminary. 2/ Forecast.

Table 15--Linseed oil, supply and disappearance, United States, 1985/86-1992/93

Year beginning June 1	Supply			Disappearance			
	Beginning stocks	Production	Total	Exports	Domestic	Total	Ending stocks
	--1,000 short tons--						
1985/86	33	205	238	15	184	199	39
1986/87	39	201	240	6	183	189	51
1987/88	51	217	268	8	219	227	41
1988/89	41	170	211	12	151	163	48
1989/90	48	165	213	12	164	176	37
1990/91	37	176	213	6	167	173	40
1991/92 1/	40	176	216	10	166	176	40
1992/93 2/	40	176	216	10	166	176	40

1/ Preliminary. 2/ Forecast.

Table 16--Linseed meal, supply and disappearance, United States, 1985/86-1992/93

Year beginning June 1	Supply				Disappearance			
	Beginning stocks	Production	Imports	Total	Exports	Domestic	Total	Ending stocks
	--1,000 short tons--							
1985/86	3	184	3	190	75	110	185	5
1986/87	5	185	2	192	63	127	190	2
1987/88	2	198	2	202	59	140	199	3
1988/89	3	156	11	170	63	102	165	5
1989/90	5	153	9	167	23	139	162	5
1990/91	5	162	3	170	41	124	165	5
1991/92 1/	5	162	3	170	35	130	165	5
1992/93 2/	5	162	3	170	30	135	165	5

1/ Preliminary. 2/ Forecast.

Table 17--Industrial rapeseed, supply, disappearance, and price, United States, 1987/88-1992/93

Year beginning June 1	Supply			Disappearance				Price
	Beginning stocks	Production	Total	Exports 1/	Domestic	Total	Ending stocks	Minn-eapolis
	--Million pounds--							Cents/lb.
1987/88	2,198	21,981	24,179	0	23,072	23,072	1,107	10.00
1988/89	1,107	15,822	16,929	0	16,188	16,188	741	11.10
1989/90	741	19,143	19,884	0	19,003	19,003	882	10.50
1990/91	882	22,717	23,599	0	22,319	22,319	1,279	10.30
1991/92 2/	1,279	16,146	17,425	0	17,158	17,158	267	10.10
1992/93 3/	267	14,455	14,722	0	14,522	14,522	200	10.00

1/ Trade data does not distinguish between industrial and edible (canola) exports, therefore all exports were allocated to canola. 2/ Preliminary. 3/ Forecast.

Table 18--Industrial rapeseed oil, supply, disappearance, and price, United States, 1987/88-1992/93

Year beginning June 1	Supply				Disappearance				Price
	Beginning stocks	Production	Imports	Total	Exports 1/	Domestic	Total	Ending stocks	Minn-eapolis
	--Million pounds--								Cents/lb
1987/88	800	6,785	17,637	25,222	0	22,699	22,699	2,522	23.60
1988/89	2,522	6,858	35,274	44,654	0	40,188	40,188	4,465	25.60
1989/90	4,465	8,184	29,407	42,056	0	37,851	37,851	4,206	27.80
1990/91	4,206	6,960	20,657	31,823	0	28,640	28,640	3,182	24.50
1991/92 2/	3,182	5,705	8,647	17,534	0	15,780	15,780	1,753	22.60
1992/93 3/	1,753	6,334	9,968	18,055	0	16,250	16,250	1,806	24.30

1/ Trade data does not distinguish between industrial and edible (canola) exports, therefore all exports were allocated to canola. 2/ Preliminary. 3/ Forecast.

Table 19--Industrial rapeseed meal, supply, disappearance, and price, United States, 1987/88-1992/93

Year beginning June 1	Supply				Disappearance				Price
	Beginning stocks	Production	Imports	Total	Exports	Domestic	Total	Ending stocks	Minn-eapolis
	--Million pounds--								Cents/lb
1987/88	300	10,624	0	10,924	0	10,711	10,711	212	168.00
1988/89	212	10,738	0	10,950	0	10,736	10,736	215	177.00
1989/90	215	12,815	0	13,030	0	12,773	12,773	256	149.00
1990/91	256	10,897	0	11,153	0	10,935	10,935	218	145.00
1991/92 1/	218	8,933	0	9,151	0	9,017	9,017	134	151.00
1992/93 2/	134	9,918	0	10,052	0	9,903	9,903	149	144.00

1/ Preliminary. 2/ Forecast.

Table 20--Total fats and oils consumption, with inedible by category, United States, 1985/86-92

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
	--Million pounds--									
1985/86	19,249.6	13,972.6	5,277.0	754.9	228.0	1,705.7	173.4	103.4	1,968.9	342.6
1986/87	d	d	5,990.6	d	d	d	d	d	d	d
1987/88	20,241.2	14,175.5	6,065.7	868.6	179.1	1,967.6	196.3	107.8	2,203.8	542.8
1988/89	19,426.7	13,542.0	5,884.7	744.5	180.3	2,079.3	202.3	115.8	2,074.1	488.4
1989/90	20,036.0	14,382.7	5,653.3	792.0	89.5	2,143.5	222.4	157.1	1,944.7	304.1
1991	20,332.1	14,613.0	5,719.1	832.9	106.8	1,974.0	182.6	101.7	2,234.7	286.4
1992	20,751.7	14,847.3	5,904.4	738.8	123.8	2,176.5	165.5	109.4	2,041.2	549.3

d = Data withheld to avoid disclosing figures for individual companies.
1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.
Source: Bureau of Census.

Table 21--Castor oil consumption, with inedible by category, United States, 1985/86-92

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
	--Million pounds--									
1985/86	59.9	0.0	59.9	d	d	0.0	4.5	d	d	d
1986/87	70.4	0.0	70.4	d	4.6	0.0	4.2	5.6	d	53.8
1987/88	74.6	0.0	74.6	d	4.3	0.0	4.8	6.1	d	59.0
1988/89	59.2	0.0	59.2	d	4.8	0.0	4.5	6.2	0.0	43.2
1989/90	51.4	0.0	51.4	d	5.9	0.0	4.0	5.7	0.0	d
1991	46.0	0.0	46.0	d	5.9	0.0	4.0	d	0.0	31.7
1992	41.3	0.0	41.3	d	d	0.0	3.3	3.5	0.0	28.4

d = Data withheld to avoid disclosing figures for individual companies.
1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.
Source: Bureau of Census.

Table 22--Coconut oil consumption, with inedible by category, United States, 1985/86-92

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
	--Million pounds--									
1985/86	634.7	332.8	301.9	123.2	d	0.0	d	d	59.7	d
1986/87	858.2	319.4	538.8	216.1	d	0.0	d	d	95.7	d
1987/88	788.6	233.4	555.4	213.8	d	0.0	7.2	d	131.4	d
1988/89	688.8	211.2	477.6	130.6	1.4	d	14.6	d	121.9	206.6
1989/90	525.2	160.6	364.6	156.9	2.1	0.0	9.7	4.0	134.6	57.3
1991	815.6	153.0	662.6	158.0	d	d	2.4	d	426.7	72.8
1992	875.4	176.3	699.1	121.7	d	0.0	3.2	d	d	d

d = Data withheld to avoid disclosing figures for individual companies.
1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.
Source: Bureau of Census.

Table 23--Edible tallow consumption, with inedible by category, United States, 1985/86-92

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
	--Million pounds--									
1985/86	1,080.2	1,020.9	59.2	d	0.0	0.0	0.0	d	d	d
1986/87	979.2	910.6	68.6	d	0.0	0.0	d	d	d	d
1987/88	954.3	863.6	90.5	d	0.0	0.0	d	d	d	d
1988/89	923.3	779.2	144.1	d	0.0	d	d	d	d	d
1989/90	846.4	706.3	140.1	113.9	0.0	d	d	d	d	d
1991	611.8	463.1	148.7	d	0.0	d	d	d	d	d
1992	595.0	429.3	165.7	d	0.0	d	d	d	d	d

d = Data withheld to avoid disclosing figures for individual companies.
1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.
Source: Bureau of Census.

Table 24--Inedible tallow consumption, with inedible by category, United States, 1985/86-92

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1985/86	2,878.5	0.0	2,878.5	492.3	0.0	1,550.5	0.0	62.8	733.4	39.5
1986/87	3,040.9	0.0	3,040.9	543.6	0.0	1,698.9	0.0	70.3	693.6	35.1
1987/88	3,137.8	0.0	3,137.8	502.0	0.0	1,820.3	0.0	69.9	712.6	33.0
1988/89	3,086.7	0.0	3,086.7	374.9	0.0	1,925.4	0.0	70.3	680.0	36.1
1989/90	3,219.0	0.0	3,219.0	398.4	0.0	1,982.9	0.0	109.0	684.0	44.7
1991	2,949.3	0.0	2,949.3	391.5	0.0	1,748.4	0.0	59.6	700.9	48.9
1992	3,050.1	0.0	3,050.1	334.4	0.0	1,954.4	0.0	63.2	659.0	39.1

d = Data withheld to avoid disclosing figures for individual companies.
1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.
Source: Bureau of Census.

Table 25--Lard consumption, with inedible by category, United States, 1985/86-92

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1985/86	405.8	355.0	50.8	0.0	0.0	d	0.0	7.2	d	d
1986/87	301.2	240.9	60.3	d	0.0	d	0.0	6.2	d	d
1987/88	347.5	280.3	66.9	d	0.0	d	0.0	8.4	d	d
1988/89	389.9	324.5	65.4	0.0	0.0	d	0.0	d	d	d
1989/90	369.3	303.8	65.5	d	0.0	d	0.0	9.1	d	d
1991	393.1	313.8	79.3	0.0	0.0	d	0.0	5.7	d	4.1
1992	479.7	345.0	134.6	0.0	0.0	d	0.0	10.9	d	13.5

d = Data withheld to avoid disclosing figures for individual companies.
1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.
Source: Bureau of Census.

Table 26--Linseed oil consumption, with inedible by category, United States, 1985/86-92

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1985/86	176.9	0.0	176.9	0.0	131.0	0.0	29.7	d	d	d
1986/87	280.8	0.0	280.8	0.0	187.6	0.0	d	d	d	d
1987/88	159.3	0.0	159.3	0.0	85.5	0.0	31.0	d	d	40.5
1988/89	154.9	0.0	154.9	0.0	101.6	0.0	23.1	d	d	28.2
1989/90	110.5	0.0	110.5	0.0	30.3	d	52.5	d	d	23.8
1991	95.8	0.0	95.8	0.0	40.7	0.0	41.6	d	d	12.7
1992	154.4	0.0	154.4	0.0	69.0	0.0	31.3	d	d	d

d = Data withheld to avoid disclosing figures for individual companies.
1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.
Source: Bureau of Census.

Table 27--Palm oil consumption, with inedible by category, United States, 1985/86-92

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1985/86	398.1	364.0	34.1	d	0.0	d	0.0	d	d	d
1986/87	317.9	278.7	39.2	d	d	d	d	d	d	d
1987/88	242.6	197.5	45.1	d	d	d	d	d	d	d
1988/89	247.0	203.8	43.2	d	0.0	d	d	0.0	d	d
1989/90	177.7	124.0	53.7	d	0.0	d	0.0	d	d	d
1991	d	d	d	d	0.0	d	0.0	d	d	d
1992	220.5	108.1	112.4	d	0.0	d	0.0	d	40.6	3.6

d = Data withheld to avoid disclosing figures for individual companies.
1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.
Source: Bureau of Census.

Table 28--Rapeseed oil consumption, with inedible by category, United States, 1989/90-92 1/

Year 2/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 3/	Fatty acids	Other products
					--Million pounds--					
1989/90	d	265.0	d	0.0	d	d	d	d	d	d
1991	d	285.1	d	0.0	0.0	d	0.0	d	d	d
1992	d	360.5	d	0.0	0.0	d	0.0	d	d	d

d = Data withheld to avoid disclosing figures for individual companies.

1/ Includes both canola and industrial rapeseed. 2/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 3/ Includes similar oils.

Source: Bureau of Census.

Table 29--Soybean oil consumption, with inedible by category, United States, 1985/86-92

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1985/86	10,283.3	10,003.7	279.5	d	59.5	d	98.7	d	31.5	d
1986/87	10,512.2	10,212.7	299.5	d	63.2	d	109.2	d	d	65.3
1987/88	10,714.5	10,429.1	285.3	2.7	54.1	d	106.1	d	d	72.3
1988/89	9,917.6	9,635.8	281.8	1.5	34.9	d	123.7	d	d	68.2
1989/90	10,808.3	10,536.7	271.6	d	38.2	d	112.4	d	d	52.4
1991	11,267.7	10,966.7	301.0	d	49.2	d	104.7	d	d	40.4
1992	11,471.6	11,168.7	302.8	d	43.5	22.3	94.0	5.9	d	69.8

d = Data withheld to avoid disclosing figures for individual companies.

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Bureau of Census.

Table 30--Tall oil consumption, with inedible by category, United States, 1985/86-92

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1985/86	1,143.4	0.0	1,143.4	12.8	17.0	0.0	15.6	12.0	1,055.2	30.8
1986/87	1,227.0	0.0	1,227.0	12.2	d	0.0	15.7	12.9	1,152.6	19.2
1987/88	1,269.4	0.0	1,269.4	16.8	23.3	0.0	20.9	9.6	1,181.1	17.8
1988/89	1,234.3	0.0	1,234.3	8.3	31.8	0.0	18.0	8.1	1,157.3	10.8
1989/90	1,024.7	0.0	1,024.7	8.4	7.4	0.0	21.7	7.1	969.9	10.2
1991	940.0	0.0	940.0	3.5	5.4	0.0	11.6	4.0	906.5	9.0
1992	883.5	0.0	883.5	d	d	0.0	19.4	7.0	841.8	11.4

d = Data withheld to avoid disclosing figures for individual companies.

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Bureau of Census.

Table 31--Vegetable oil foots consumption, with inedible by category, United States, 1985/86-92

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1985/86	99.2	0.0	99.2	d	d	d	d	d	d	d
1986/87	94.9	0.0	94.9	d	d	d	d	d	d	d
1987/88	91.1	0.0	91.1	d	d	74.3	d	d	d	d
1988/89	87.5	0.0	87.5	d	d	72.7	d	d	d	d
1989/90	100.1	0.0	100.1	d	d	81.7	d	d	d	d
1991	148.8	0.0	148.8	d	0.0	131.4	d	d	d	d
1992	134.9	0.0	134.9	d	0.0	120.2	0.0	d	d	d

d = Data withheld to avoid disclosing figures for individual companies.

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Bureau of Census.

Table 32--Canola oil prices, Midwest markets, 1989-93

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents/pound--							
1989	25.00	25.30	26.40	26.25	25.55	23.44	22.50	22.38	23.00	23.19	25.31	25.60	24.49
1990	26.69	27.50	28.94	29.25	31.15	27.19	25.31	26.90	18.38	24.38	24.63	23.13	26.12
1991	24.00	23.56	24.38	24.88	24.25	23.75	22.90	23.94	24.56	23.05	23.38	22.42	23.76
1992	22.25	21.75	21.75	20.75	22.00	22.31	20.94	20.69	22.90	22.19	24.38	23.08	22.08
1993	22.08												

Source: Milling and Baking News.

Table 33--Castor oil prices, raw No. 1, tanks, Brazilian, 1989-93

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents/pound--							
1989	51.00	51.75	51.90	51.50	51.50	51.50	51.50	51.50	41.20	51.50	51.50	53.75	50.84
1990	54.50	53.50	52.60	52.00	51.20	51.00	51.00	51.00	45.00	42.40	39.63	39.63	48.62
1991	39.30	36.00	36.75	37.00	37.00	36.50	35.50	35.00	35.00	35.40	35.00	37.50	36.33
1992	37.50	37.50	37.50	36.00	34.50	34.50	34.50	34.50	34.00	34.00	34.00	34.00	35.21
1993	34.00	32.00	32.00	37.00									

Source: Chemical Marketing Reporter.

Table 34--Coconut oil prices, crude, tanks, f.o.b. New York, 1989-93

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents/pound--							
1989	26.75	27.63	27.90	28.94	29.90	29.56	28.94	27.75	28.63	27.25	26.35	24.81	27.87
1990	24.31	23.69	22.10	21.63	21.30	20.31	19.16	18.58	18.26	18.18	20.45	20.13	20.67
1991	20.22	20.31	20.50	19.38	19.69	21.69	26.19	25.63	25.63	28.50	31.50	32.38	24.30
1992	39.33	36.00	34.57	34.75	33.56	32.13	29.63	27.31	27.88	26.94	27.00	25.50	31.22
1993	24.94	24.33	23.65	23.25	24.13								

Source: Chemical Marketing Reporter.

Table 35--Edible tallow prices, Chicago, 1989-93

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents/pound--							
1989	16.50	16.07	16.25	15.75	16.19	16.00	15.73	15.33	16.50	16.18	N.A.	N.A.	13.37
1990	16.77	17.16	15.46	14.25	14.20	14.28	14.21	10.53	13.76	14.55	15.00	15.28	14.62
1991	15.88	14.28	14.43	14.80	13.02	13.25	13.70	14.61	14.37	14.60	14.09	14.00	14.25
1992	14.05	14.00	14.15	14.28	14.66	15.37	15.87	16.00	16.05	16.88	18.18	17.00	15.54
1993	16.08	15.39	16.07										

N.A. = Not available.

Source: Grain and Feed Marketing News.

Table 36--Flaxseed, average price received by farmers, 1989-93

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Dollars/bushel--							
1989	8.34	8.70	8.09	7.78	7.54	6.79	5.90	6.49	7.07	7.09	7.15	7.14	7.29
1990	7.24	7.69	8.03	8.60	8.23	8.31	7.56	5.86	5.36	5.15	5.16	5.15	5.53
1991	5.12	4.80	4.90	4.66	4.33	3.98	3.91	3.69	3.55	3.40	3.31	3.46	3.57
1992	3.39	3.43	3.52	3.53	3.61	3.67	3.70	3.71	4.12	4.09	4.10	4.21	3.94
1993	4.12	4.47	4.54	4.41	4.35								

Source: National Agricultural Statistical Service, USDA.

Table 37--Industrial rapeseed oil prices, refined, tanks, New York, 1989-93

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents/pound--							
1989	70.00	70.00	80.25	80.25	80.25	80.25	80.25	80.25	80.25	64.20	80.25	80.25	77.20
1990	81.75	82.25	82.25	82.25	82.25	82.25	82.25	82.25	79.75	77.25	77.25	81.00	81.06
1991	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25
1992	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	67.25	62.25	62.25	62.25	76.00
1993	62.25	62.25	62.25	62.25	55.88								

Source: Chemical Marketing Reporter.

Table 38--Inedible tallow prices, Chicago, 1989-93

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents/pound--							
1989	14.90	16.00	14.86	14.60	14.70	15.10	14.48	13.52	14.13	10.94	14.75	14.25	14.35
1990	14.87	14.50	14.47	13.50	13.51	14.01	13.50	10.12	13.50	13.42	14.09	14.50	13.67
1991	14.53	12.91	13.63	13.57	12.25	12.36	12.96	14.00	13.50	13.68	13.08	12.50	13.25
1992	N.A.	12.63	12.68	13.25	13.75	13.98	14.75	15.42	15.25	15.73	16.75	13.52	14.34
1993	15.09	14.69	15.24	15.94	15.13								

N.A. = Not available.

Source: Grain and Feed Marketing News.

Table 39--Linseed oil prices, tanks, Minneapolis, 1989-93

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents/pound--							
1989	41.00	41.00	41.40	42.00	42.00	39.75	39.00	39.00	39.50	40.00	40.00	39.50	40.35
1990	40.00	40.00	41.60	42.00	42.00	43.00	44.00	40.40	39.75	36.80	36.00	36.00	40.13
1991	36.00	36.00	36.00	36.00	36.50	36.00	36.00	36.00	36.00	30.00	30.00	30.00	34.54
1992	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	32.00	32.00	32.00	32.00	28.17
1993	32.00	32.00	32.00	32.00	32.00								

Source: Grain and Feed Marketing News.

Table 40--Linseed meal prices, bulk, 34 percent protein, Minneapolis, 1989-93

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Dollars/tons--							
1989	164.00	151.25	150.00	155.00	156.00	162.50	158.75	161.00	145.00	129.00	126.25	128.75	148.96
1990	132.50	124.50	126.25	133.75	143.00	142.50	136.00	126.25	116.25	133.00	143.75	133.50	132.60
1991	131.00	131.25	120.00	121.00	126.25	134.25	133.00	131.25	116.25	128.00	113.75	127.80	126.15
1992	122.00	124.00	115.00	117.50	120.00	125.00	123.50	126.25	131.00	141.25	152.50	137.40	127.95
1993	136.70	142.50	135.40	125.50									

N.A. = Not available.

Source: Grain and Feed Marketing News.

Table 41--Soybean oil prices, crude, tanks, f.o.b. Decatur, 1989-93

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents/pound--							
1989	21.13	21.21	22.11	21.97	22.23	20.75	19.66	18.08	18.77	19.02	19.57	19.11	21.09
1990	19.28	20.27	22.80	23.35	24.72	25.03	24.69	25.05	24.45	22.59	21.05	21.55	22.28
1991	21.56	21.66	22.21	21.50	20.23	19.65	19.05	20.23	20.46	19.57	18.78	18.99	20.98
1992	18.77	18.88	19.74	19.00	20.15	20.71	18.82	17.87	18.28	18.36	20.10	20.52	19.13
1993	21.23	20.72	21.00	21.24	21.15								

Source: The Wall Street Journal.

Table 42--World production of jojoba seed, 1992/93

Country and source	Production
	Pounds
United States	
Native stands 1/	36,372
Plantations	4,110,503
Total	4,146,875
Mexico	
Native stands 1/	79,809
Plantations	216,051
Total	295,860
Israel	
Plantations	320,000
Argentina	
Plantations 2/	250,000
Total estimated seed production	5,012,735
Total estimated oil production	2,025,200

1/ Amount of processed seed. Unknown quantities of unprocessed seed may be held in inventory. 2/ Estimated.

Source: Jojoba Association.

Table 43--U.S. natural rubber latex imports, by country, 1989-92

Country	1989	1990	1991	1992
	--Metric tons--			
Malaysia	47,281,074	30,647,643	40,000,125	45,279,103
Singapore	3,002,828	3,148,579	6,803,119	564,895
Sri Lanka	244,768	257,566	256,217	216,601
Thailand	7,507,633	3,418,870	4,120,504	4,129,368
Other	61,755,077	34,984,788	27,859,374	36,461,643
Total	119,791,380	72,457,446	79,039,339	86,651,610

Source: International Rubber Study Group.

Table 44--U.S. natural rubber latex exports, by country, 1989-92

Country	1989	1990	1991	1992
	--Metric tons--			
Canada	12,185,785	3,227,593	3,027,736	1,820,378
Italy	1,134,076	908,833	908,833	1,075,446
Venezuela	741,103	1,115,554	324,467	120,071
Mexico	711,748	989,194	892,819	1,589,600
Singapore	502,050	31,939	31,939	38,518
Chile	276,223	188,569	278,567	132,340
Japan	262,814	629,970	714,781	720,519
Sweden	235,930	61,435	52,509	6,261
United Kingdom	207,673	227,511	287,345	66,154
Germany	133,937	262,349	403,486	151,613
Other 1/	1,277,459	1,664,326	2,029,626	1,739,865
Total	17,668,798	9,307,273	8,952,108	7,460,765

1/ Includes 62 countries.

Source: International Rubber Study Group.

List Prices

The following are list prices from the Chemical Marketing Reporter for selected chemicals and related materials on a New York or other indicated basis. They do not represent bid, asked, or actual transaction prices. Variations from listed prices may occur for differences in quantity, quality, and location. Commodities whose list prices did not change more than once or twice since January 1989 are not included here.

Table 45--Denatured alcohol prices, ethyl (ethanol), SD2B, tanks delivered east, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
							--Dollars/gallons--						
1989	2.01	2.01	2.01	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.09
1990	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11
1991	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.02	2.02	2.02	2.02	2.08
1992	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02	2.02
1993	2.02	2.02	2.02	2.02	2.02								

1/ Made by yeast fermentation of carbohydrates or by hydrolysis of ethylene for solvents, cosmetics, and oxygenated gasoline additive.

Source: Chemical Marketing Reporter.

Table 46--Dextrin prices, corn, canary dark, 100 lb. bags, carload, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
							--Cents/pound--						
1989	28.04	28.04	28.04	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	31.01
1990	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00
1991	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00
1992	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00	32.00
1993	32.00	32.00	32.00	32.00	32.00								

1/ Obtained by heating acidified dry starch for adhesives and paper products.

Source: Chemical Marketing Reporter.

Table 47--Dextrose prices, hydrated, commercial, 100 lb. bags, carloads delivered, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
							--Cents/pound--						
1989	24.25	24.25	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.29
1990	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50
1991	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50
1992	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50	25.50
1993	25.50	25.50	25.50	25.50	25.50								

1/ Obtained from corn starch hydrolysis for use in foods and as a fermentation substrate.

Source: Chemical Marketing Reporter.

Table 48--Furfural prices, tanks, f.o.b., 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
							--Cents/pound--						
1989	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00	75.00
1990	75.00	75.00	75.00	75.00	75.00	79.00	79.00	79.00	79.00	79.00	79.00	79.00	77.33
1991	79.00	79.00	79.00	79.00	79.00	79.00	79.00	79.00	79.00	79.00	79.00	79.00	79.00
1992	79.00	79.00	79.00	79.00	79.00	79.00	79.00	79.00	79.00	79.00	79.00	79.00	79.00
1993	79.00	79.00	79.00	79.00	79.00								

1/ Obtained by steam distillation of acidified plant materials for polymers and foundry binders.

Source: Chemical Marketing Reporter.

Table 49--Sorbitol prices, USP, regular, 70 percent aqueous, drums, carload, f.o.b., 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents/pound--							
1989	38.00	38.00	39.00	39.00	39.00	39.00	40.50	40.50	40.50	40.50	40.50	40.50	39.58
1990	40.50	40.50	40.50	40.50	40.50	40.50	40.50	40.50	40.50	40.50	40.50	36.50	40.17
1991	36.50	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.29
1992	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00
1993	33.00	33.00	33.00	33.00	33.00								

1/ Hydrogenation of glucose for foods, cosmetics, and polyester polymers. Prices quoted are low end of a range.

Source: Chemical Marketing Reporter.

Table 50--Beeswax prices, refined, bleached white bricks, 100 lb. cartons, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Dollars per pound--							
1989	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10
1990	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10
1991	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10
1992	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.35	3.12
1993	3.35	3.35	3.35	3.35	3.35								

1/ A byproduct of honey production used for cosmetics and candles. Price quotes are low end of a range.

Source: Chemical Marketing Reporter.

Table 51--Capric acid prices, commercial, pure, tanks, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents per gallon--							
1989	66.00	66.00	66.00	66.00	66.00	66.00	66.00	66.00	73.00	73.00	73.00	73.00	68.33
1990	73.00	73.00	73.00	73.00	73.00	73.00	73.00	73.00	83.00	83.00	83.00	83.00	76.33
1991	83.00	83.00	83.00	83.00	83.00	83.00	83.00	83.00	83.00	83.00	83.00	83.00	83.00
1992	83.00	83.00	83.00	83.00	83.00	83.00	83.00	92.00	92.00	92.00	92.00	92.00	86.75
1993	92.00	92.00	92.00	92.00	92.00								

1/ Fatty acid obtained from coconut oil.

Source: Chemical Marketing Reporter.

Table 52--Caprylic acid prices, commercial, pure, tanks, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents per pound--							
1989	64.00	64.00	74.00	74.00	74.00	74.00	74.00	74.00	74.00	76.00	76.00	76.00	72.83
1990	76.00	76.00	76.00	76.00	76.00	76.00	76.00	76.00	83.00	83.00	83.00	83.00	78.33
1991	83.00	83.00	83.00	83.00	83.00	83.00	83.00	83.00	83.00	83.00	83.00	83.00	83.00
1992	83.00	83.00	83.00	83.00	83.00	83.00	83.00	102.00	102.00	102.00	102.00	102.00	90.92
1993	102.00	102.00	102.00	102.00	102.00								

1/ Fatty acid obtained from coconut oil.

Source: Chemical Marketing Reporter.

Table 53--Glycerine prices, natural, refined, USP, 99.7 percent, tanks, delivered, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents per pound--							
1989	76.00	76.00	76.00	76.00	76.00	76.00	82.00	82.00	82.00	82.00	82.00	82.00	79.00
1990	82.00	82.00	82.00	77.00	73.00	73.00	73.00	73.00	73.00	73.00	75.00	75.00	75.92
1991	75.00	75.00	75.00	63.00	63.00	63.00	63.00	63.00	63.00	63.00	51.00	51.00	64.00
1992	51.00	51.00	51.00	58.50	58.50	58.50	58.50	58.50	58.50	58.50	58.50	58.50	56.63
1993	58.50	58.50	58.50	58.50	58.50								

1/ Byproduct of splitting or saponification of fats and oils or made by petrochemical synthesis for cosmetics, food, drugs, and polyurethane polymers.

Source: Chemical Marketing Reporter.

Table 54--Jojoba oil prices, 2,200 lbs. or more, f.o.b. Arizona, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Dollars per kilogram--							
1989	14.18	14.18	14.18	14.18	14.18	14.18	15.25	15.25	15.25	15.25	15.25	15.25	14.72
1990	15.25	20.02	20.02	20.02	20.02	20.02	26.00	26.00	25.00	25.00	24.00	24.00	22.11
1991	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	21.00	15.50	15.50	15.50	21.63
1992	15.50	15.50	15.50	15.50	15.50	15.50	15.50	13.50	13.50	11.99	11.99	11.99	14.29
1993	11.99	11.99	11.99	11.99	11.99								

1/ Price quotes are the low end of a range.

Source: Chemical Marketing Reporter.

Table 55--Lard oil prices, tanks, f.o.b., 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents per pound--							
1989	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
1990	30.00	30.00	30.00	30.00	30.00	30.00	30.00	47.00	47.00	47.00	47.00	47.00	37.08
1991	47.00	47.00	47.00	47.00	47.00	47.00	47.00	47.00	47.00	47.00	47.00	47.00	47.00
1992	47.00	47.00	47.00	47.00	47.00	47.00	47.00	47.00	47.00	47.00	47.00	47.00	47.00
1993	47.00	35.00	35.00	35.00	35.00								

1/ Rendered from pork fat for cutting oils and leather processing.

Source: Chemical Marketing Reporter.

Table 56--Lauric acid prices, commercial, pure bags, truckload, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents per pound--							
1989	56.00	56.00	56.00	56.00	56.00	56.00	56.00	56.00	61.00	61.00	61.00	61.00	57.67
1990	61.00	61.00	61.00	61.00	61.00	61.00	61.00	61.00	65.50	65.50	65.50	65.50	62.50
1991	65.50	65.50	65.50	54.50	54.50	54.50	54.50	54.50	54.50	54.50	54.50	54.50	57.25
1992	54.50	54.50	54.50	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	62.38
1993	65.00	65.00	65.00	65.00	65.00								

1/ The major fatty acid (45 to 50 percent) in coconut oil. Price quotes are the low end of a range.

Source: Chemical Marketing Reporter.

Table 57--Lecithin prices, unbleached, bulk, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents per pound--							
1989	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00
1990	38.00	38.00	38.00	38.00	38.00	38.00	38.00	32.00	32.00	32.00	29.00	29.00	35.00
1991	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00
1992	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	26.00	26.00	26.00	26.00	28.00
1993	26.00	26.00	26.00	26.00	26.00								

1/ Byproduct of soy oil extraction used as an emulsifying agent and antioxidant in foods.

Source: Chemical Marketing Reporter.

Table 58--Neatsfoot oil prices, 20 deg. F. drums, truckload, f.o.b., 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents per pound--							
1989	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00
1990	54.00	54.00	54.00	54.00	54.00	54.00	70.00	70.00	70.00	70.00	70.00	70.00	62.00
1991	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00
1992	70.00	70.00	70.00	70.00	70.00	70.00	70.00	70.00	72.50	72.50	72.50	72.50	70.83
1993	72.50	65.00	65.00	65.00	65.00								

1/ Extract from feet/hoofs of slaughtered animals for specialty leather dressings.

Source: Chemical Marketing Reporter.

Table 59--Oleic acid prices, double distilled (white), tanks, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents per pound--							
1989	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00
1990	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00
1991	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00
1992	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00
1993	54.00	61.00	61.00	61.00	61.00								

1/ Obtained by fractional crystallization from mixed fatty acids for candles, soaps, and synthesis of other surfactants.

Source: Chemical Marketing Reporter.

Table 60--Palm kernel oil prices, bulk, c.i.f. U.S. ports, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents per pound--							
1989	25.00	25.00	23.00	23.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00
1990	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00
1991	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00
1992	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00	17.00
1993	23.00	23.00	23.00	23.00	23.00								

1/ Extracted from the seed kernels of palm trees for food products and soap.

Source: Chemical Marketing Reporter.

Table 61--Sebacic acid prices, CP bags, carload, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Dollars per pound--							
1989	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	2.05	2.05	2.05	1.97
1990	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05
1991	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05
1992	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05
1993	2.05	2.05	2.05	2.05	2.05								

1/ Made by high temperature cleavage of castor oil for use as an intermediate chemical in the manufacture of polymers and plasticizers.

Source: Chemical Marketing Reporter.

Table 62--Stearic acid prices, single pressed, bulk, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents per pound--							
1989	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.00
1990	37.00	37.00	37.00	37.00	37.00	37.00	41.00	41.00	41.00	41.00	36.00	36.00	38.17
1991	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00
1992	36.00	36.00	36.00	36.00	36.00	36.00	36.00	36.00	39.00	39.00	39.00	44.00	37.42
1993	44.00	44.00	44.00	44.00	44.00								

1/ Obtained by hydrogenation of oils and fats for lubricating greases, soaps, and lubricants.

Source: Chemical Marketing Reporter.

Table 63--Tallow fatty acids prices, tanks, delivered, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents per pound--							
1989	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00
1990	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00	29.00
1991	29.00	29.00	29.00	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	24.88
1992	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50	23.50
1993	23.50	23.50	23.50	23.50	23.50								

1/ Made from splitting tallow for direct use as lubricants or in greases and for separation into pure fatty acids. Prices quoted are the low end of a range.

Source: Chemical Marketing Reporter.

Table 64--Bone phosphate, feed grade, 18.5 percent phosphorus, bulk, carload, truckload, f.o.b., 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Dollars per ton--							
1989	195.00	195.00	195.00	195.00	195.00	195.00	195.00	195.00	195.00	195.00	195.00	195.00	195.00
1990	195.00	195.00	195.00	195.00	195.00	195.00	195.00	195.00	195.00	195.00	195.00	195.00	195.00
1991	195.00	195.00	195.00	195.00	195.00	195.00	195.00	228.00	228.00	228.00	228.00	228.00	208.75
1992	228.00	228.00	228.00	228.00	228.00	228.00	228.00	228.00	228.00	228.00	195.00	195.00	222.50
1993	195.00	195.00	195.00	195.00	N.A.								

N.A.= Not available.

1/ Extracted from cooked bones for feed and fertilizer.

Source: Chemical Marketing Reporter.

Table 65--Casein prices, imported, acid precipitated, ground, 30-mesh, edible, c.i.f., 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Dollars per pound--							
1989	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
1990	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
1991	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
1992	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.55	2.55	2.55	2.55	2.52
1993	2.55	2.55	2.55	2.55	2.55								

1/ Coagulated and dried milk protein for adhesives and plastics.

Source: Chemical Marketing Reporter.

Table 66--Gelatin prices, edible, 100 AOAC test, drums, delivered, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents per pound--							
1989	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1990	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1991	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.65	1.65	1.65	1.54
1992	1.65	1.65	1.65	1.65	1.65	1.65	1.70	1.70	1.70	1.70	1.70	1.70	1.68
1993	1.70	1.70	1.70	1.70	1.70								

1/ Water extract of bones and hides for photographic emulsions and food. Price quotes are the low end of a range.

Source: Chemical Marketing Reporter.

Table 67--Glue, bone prices, extracted, green, 85 jellygrams, bags, carload, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents per pound--							
1989	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00
1990	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00
1991	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00
1992	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	89.00	89.00	94.00
1993	89.00	89.00	89.00	89.00	89.00								

1/ Steam treatment and water extraction of bones for glue and mineral flotation processes.

Source: Chemical Marketing Reporter.

Table 68--Lanolin prices, anhydrous, pharmaceutical 400 lb. drums, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Dollars per pound--							
1989	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
1990	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	1.28	1.28	0.95	1.01
1991	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	1.25	1.25	1.00
1992	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
1993	1.25	1.25	1.25	1.25	1.25								

1/ Extracted from wool for cosmetics, leather dressing, and lubricants. Price quotes are the low end of a range.

Source: Chemical Marketing Reporter.

Table 69--Alpha pinene prices, technical grade, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents per pound--							
1989	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00
1990	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00
1991	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00
1992	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00	43.00
1993	43.00	43.00	43.00	43.00	43.00								

1/ Separated from turpentine for chemical synthesis.

Source: Chemical Marketing Reporter.

Table 70--Beta pinene prices, technical grade, tanks, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents per pound--							
1989	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.00
1990	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00
1991	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00
1992	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00	55.00
1993	55.00	55.00	55.00	55.00	55.00								

1/ Separated from turpentine for chemical synthesis.

Source: Chemical Marketing Reporter.

Table 71--Carboxymethyl cellulose prices, technical, 96 percent minimum low or medium viscosity, bags, 24,000 lbs., f.o.b. Hopewell, VA, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Dollars per pound--							
1989	1.25	1.25	1.25	1.25	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.16
1990	1.18	1.18	1.18	1.18	1.18	1.45	1.55	1.55	1.55	1.55	1.55	1.55	1.39
1991	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55
1992	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55
1993	1.55	1.55	1.55	1.55	1.55								

1/ Reaction of cellulose with sodium chloroacetate for food, cosmetics, paper products, and drilling muds. Price quotes are low end of a range.

Source: Chemical Marketing Reporter.

Table 72--Cellulose acetate prices, powdered, bags, truckloads delivered east, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Dollars per pound--							
1989	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
1990	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58
1991	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62
1992	1.62	1.62	1.62	1.62	2.02	2.02	2.12	2.12	2.12	2.12	2.12	2.12	1.94
1993	2.12	2.12	2.12	2.12	2.12								

1/ Reaction of cellulose from wood with acetic acid for rayon textiles and cigarette filters.

Source: Chemical Marketing Reporter.

Table 73--Crude tall oil, tanks, freight equaled, Southeast, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Dollars per ton--							
1989	140.00	140.00	140.00	140.00	140.00	140.00	140.00	140.00	140.00	140.00	140.00	140.00	140.00
1990	135.00	135.00	135.00	135.00	125.00	125.00	130.00	130.00	130.00	145.00	145.00	155.00	135.42
1991	155.00	155.00	155.00	155.00	155.00	155.00	155.00	165.00	165.00	165.00	165.00	165.00	159.17
1992	165.00	165.00	165.00	155.00	155.00	155.00	155.00	145.00	145.00	135.00	135.00	135.00	150.83
1993	135.00	125.00	125.00	125.00	115.00								

1/ Byproduct of kraft paper production for refining into rosin and fatty acids.

Source: Chemical Marketing Reporter.

Table 74--Ethyl vanillin, 25 lb. drums, 500 lbs. or more, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Dollars per pound--							
1989	13.75	13.75	13.75	13.75	13.75	13.75	13.75	13.75	13.75	14.50	14.50	14.50	13.94
1990	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50
1991	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.75	14.75	14.75	14.56
1992	14.75	14.75	14.75	14.75	14.75	14.75	14.75	14.75	14.75	14.75	14.75	14.75	14.75
1993	14.75	14.75	14.75	14.75	14.75								

1/ Chemically modified vanillin from lignin for food flavoring. Price quotes are the low end of a range.

Source: Chemical Marketing Reporter.

Table 75--Pine oil prices, 80 percent minimum alcohol content, bulk, f.o.b., 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Cents per pound--							
1989	61.00	61.00	66.00	66.00	59.00	59.00	59.00	59.00	59.00	59.00	59.00	59.00	60.50
1990	68.00	68.00	68.00	68.00	68.00	68.00	68.00	68.00	68.00	68.00	68.00	72.00	68.33
1991	72.00	72.00	72.00	72.00	72.00	72.00	72.00	72.00	72.00	72.00	72.00	72.00	72.00
1992	72.00	72.00	72.00	72.00	72.00	72.00	72.00	72.00	72.00	72.00	72.00	72.00	72.00
1993	72.00	72.00	72.00	72.00	72.00								

1/ Steam distillation from pine stumps or synthesized from turpentine for household cleansers, coated paper, mineral flotation, and perfume.

Source: Chemical Marketing Reporter.

Table 76--Turpentine prices, crude sulfate, tanks, f.o.b. Southeast, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Dollars per gallon--							
1989	1.80	1.80	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.10	2.05
1990	2.00	2.00	1.90	1.80	1.80	1.80	1.70	1.60	1.60	1.50	1.50	1.80	1.75
1991	1.50	1.50	1.50	1.50	1.40	1.40	1.25	1.25	1.25	1.25	1.25	1.25	1.36
1992	1.15	1.10	1.10	0.90	0.90	0.90	0.90	0.75	0.75	0.70	0.70	0.70	0.88
1993	0.70	0.70	0.70	0.70	0.70								

1/ Paper industry byproduct for recovery of alpha and beta pinene.

Source: Chemical Marketing Reporter.

Table 77--Fir oil prices, Canada, drums, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Dollars per pound--							
1989	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75
1990	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75
1991	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75	9.75
1992	9.75	9.75	9.75	11.00	11.00	11.00	11.50	11.50	11.50	11.50	11.50	11.50	10.94
1993	11.50	11.50	11.50	11.50	11.50								

1/ Steam distilled from Picea nigra for perfumes. Price quotes are low end of a range.

Source: Chemical Marketing Reporter.

Table 78--Juniperberry oil prices, Italian, 1989-93 1/

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Avg.
						--Dollars per kilogram--							
1989	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00
1990	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	95.00	57.00	91.83
1991	57.00	57.00	57.00	220.00	220.00	220.00	220.00	220.00	220.00	220.00	220.00	220.00	179.25
1992	220.00	210.00	210.00	210.00	210.00	210.00	210.00	210.00	264.00	264.00	264.00	264.00	228.83
1993	264.00	264.00	264.00	264.00	264.00								

1/ Byproduct of gin production used for perfume. Price quotes are low end of a range.

Source: Chemical Marketing Reporter.

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